Emotion attribution and memory in the ageing brain

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I, Flávia Schechtman Belham, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Episodic memory is influenced by emotions and ageing. While emotional events elicit superior memory than neutral ones, older adults (OA) are better in shifting the valence of an episode to make it more positive. This thesis investigated the interaction between episodic memory, emotion and ageing using behavioural and event-related potentials measures. The first aim was to identify which steps in the memory process are affected by emotion and ageing. Experiment 1 showed that emotion influences encoding, and ageing influences retrieval. Experiment 2 showed that prestimulus encoding-related activity is influenced by the time available to process the upcoming emotional stimulus, suggesting that preparatory activity is a flexible, but effortful mechanism. The second aim was to use a novel evaluative conditioning procedure to investigate how neutral information acquires emotional valence and is encoded and retrieved by younger adults (YA) and OA. Participants created emotional or neutral sentences with neutral words and completed memory and likeability tasks. Experiments 3 and 4 revealed that spontaneous emotion attribution is influenced by personality traits and elicits stronger likeability changes than forced attribution. Experiments 5 and 6 showed that YA and OA can change their feelings about neutral information by attributing positive emotions. The likeability changes survive a one-week delay and are related to source memory for the attributed emotion. Experiment 7 showed that retrieval of positive emotions elicited brain activity usually related to imagery. In conclusion, emotion attribution and its relationship with memory are preserved in OA, being affected by spontaneity and individual differences. The link between likeability changes and memory may be related to the use of imagery. This thesis enhances the understanding of how episodic memory and its brain correlates are influenced by ageing when the to-be-retrieved information is intrinsically emotional or has acquired emotionality.

Impact Statement

The benefits of my thesis to knowledge are two-fold. The first advance is the study of prestimulus subsequent memory effects in older adults. Up to the writing of the thesis, no study had been published looking at how anticipatory activity develops in ageing. Thus, the findings of this thesis are likely to be of interest to different academic journals and will open a new line of ERP investigation.

The second advance of this thesis that will lead to benefits inside academia is the development of a novel procedure to investigate emotion attribution. This procedure aims to address the weaknesses of the earlier protocols to ensure that the relationship between emotion attribution and memory is studied in a more robust way. This thesis will, thus, bring together two research topics that have not been in direct touch so far: evaluative conditioning and episodic memory. This new link will lead to insights regarding consumer behaviour and also clinical interventions to treat post-traumatic stress disorder, for example.

The benefits outside of academia are many. During the PhD, I was the leader of a public engagement project funded by UCL to discuss neuroscience with older adults in London. The project was considered a success by the attendees and by UCL Public Engagement Unit. After coming to the workshop, the older adults were better informed about their own cognition, potentially misleading information from the media, and robust techniques to improve their own memory.

I also gave a talk about my findings at the Westminster School to Sixth Form students, after being invited by their head of Science. These kids were part of a group that were still undecided as to which career to pursue. By sharing exciting scientific findings, I may be increasing the number of students applying for STEM subjects at university.

I have also written science communication articles based on this thesis (see URLs on next page). One of them was for the website Know it Wall and focuses on explaining the different types of memories and how to study them. The second one was for the website NeuroMexico and focuses on discussing what happens to memory processing in ageing. This article was also translated to Spanish, giving it an even wider reach. Science communication articles have a huge positive impact on enhancing the public's knowledge of neuroscience and building a bridge between researchers and everyone else.

Link to Know it Wall article: http://knowitwall.com/episodes/why-do-we-forget-where-we-leave-our-keys-but-not-how-to-ride-a-bike/

Link to NeuroMexico article: http://www.neuromexico.org/2018/03/11/cognitive-ageing-what-happens-to-our-memory-when-we-get-older/

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Chapter 1: General introduction

The main interest of this thesis is in the interactions between memory, emotion and ageing from a behavioural and a neurophysiological point of view. It derives from findings in the literature showing that younger and older adults process and memorise emotional events in different ways, although the mechanisms that underlie such differences are not clear. This thesis also considers emotion attribution by investigating memory for neutral information that has acquired emotionality via evaluative conditioning, a novel topic in the field of cognitive ageing. As its neuroimaging technique, this thesis uses event-related potentials elicited before and after stimulus onset during encoding and also during retrieval.

Chapter 1 covers a comprehensive literature review on the interaction between memory, emotion and ageing as well as its neural correlates. The chapter begins with what is known about memory processing, focusing on episodic memory. It then goes to the ageing literature, explaining the different models and theories that have been derived from sometimes consistent and sometimes mixed findings in previous research. The chapter continues by linking memory, emotion and ageing until it reaches evaluative conditioning. Evaluative conditioning is reviewed in depth, since it is the technique used in this thesis to study the interaction between emotion attribution and memory in the ageing brain. The final part of Chapter 1 resumes the research questions and aims of this thesis.

Chapter 2 explains the neuroimaging technique used for this thesis, as well as the rationale behind the chosen behavioural paradigms. Chapters 3, 4 and 5 describe two experimental studies each. Chapter 6 offers a general discussion about the findings of this thesis, naming possible implications for the theoretical, applied and clinical literatures, as well as suggesting future directions of research.

General mechanisms of episodic memory

Mnemonic processing

Memory is the ability to acquire, retain and utilize information or knowledge. This ability is fundamental not only for our daily activities but also for our survival, by enabling us to use past knowledge to anticipate the consequences of a decision and act accordingly (Garber & Lavalle, 1999; La Cerra & Bingham, 1998; Simon & Kaplan, 1990). Memories are crucial for planning, thinking, decision-making, problem solving, amongst other important cognitive functions, and their investigation increases our understanding of human mind and behaviour (Alberini & LeDoux, 2013).

Mnemonic processing occurs in three phases. The first one is "encoding", when an external or internal stimulus is experienced and captured by the sensory systems connected to memory (Paller & Wagner, 2002). The next phase is "consolidation", where acquired information is transformed according to an individual's previous knowledge and the physiological responses generated by the stimulus create a more permanent record of the original experience (Schacter, 1990). The last phase is "retrieval", by which stored information is remembered and utilized. The efficiency with which a stimulus is acquired, consolidated and retrieved depends in part on its cognitive and emotional importance and the attentional level dispensed by the individual (Phelps, 2004). More recently, the idea of reconsolidation has gained popularity. According to this view, consolidated memories can become vulnerable and altered by factors during retrieval (Squire, 2009). In fact, this idea has been around since the 1960s, originating from studies where mice had consolidated memories lost after electroconvulsive shocks administered right after retrieval (Dudai, 2003). In humans, reconsolidation can update, weaken or strengthen an already consolidated memory. The disturbing factor can be radical, such as electrical shocks or drugs, but can also be more subtle such as reminders of previously learned stimuli (Schwabe, Nader, & Pruessner, 2014). These findings point to the malleability of memories and how different experimental manipulations and conditions can change them.

Many studies, from the classic ones with patient H.M. (Scoville & Milner, 1957) to recent neuroimaging investigations (Marks, Lockart, Baker, & Jagust, 2017) , have shown that memory for events and stimuli, mainly spatial information, is dependent on structures of the medial temporal lobe (Baddeley, 2001; Kemp & Manahan-Vaughan, 2007). It is thought that learned information is initially stored in the neocortex and later integrated with information processed by structures in the medial temporal lobe, in the form of linked mental representations (Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006). The specificities of this process are not clear. Eichenbaum, Yonelinas, and Ranganath (2007) propose that the connections between neocortex and the perirhinal cortex store the sensory information about the event, whereas the links between the neocortex and parahippocampal cortex process the contextual information. Paller and Wagner (2002) suggest that the medial temporal lobe connects to the left inferior prefrontal cortex and to the fusiform cortex when the remembered item is a word, and to the right inferior prefrontal cortex when it is a complex image.

What happens after the different pieces of information converge to the hippocampus is still being debated by different theories (Moscovitch et al., 2006). The Standard Consolidation Model suggests that, with time, the memory traces are strengthened in cortico-cortico connections which reduces, and eventually eliminates, the necessity of hippocampal contribution for their retrieval (Dudai, 2003; Frankland & Bontempi, 2005). Thus, only recent memories would require hippocampal activity, which would protect the old memories from being interfered with. A different idea comes from the Multiple Trace Theory, which claims that retrieval of episodic memory is always dependent on the hippocampal region (Moscovitch et al., 2005). According to this theory, each time a memory trace is retrieved, it is also re-encoded, which creates new memory traces and increases the strength of the mental representation of that episode. The memories that do not undergo this process become weaker, less detailed, and ultimately transform into semantic memory, being retrieved by non-hippocampal structures. According to the review by Moscovitch et al. (2006), functional magnetic resonance imaging (fMRI) and lesion studies support the Multiple Trace Theory by showing that the hippocampal region is equally activated regardless of the age of the memory. However, according to Frankland and Bontempi (2005), the Standard Consolidation Model is also supported by fMRI and lesion studies showing that the hippocampus is only relevant in old memories.

Episodic memory

Importantly, not all memories are the same. They differ in terms of storage, functioning and brain regions (Squire, 2009). For instance, when rehearsing a telephone number in one's mind on the way to the telephone, one is using working memory. This is a limited capacity multi-component system that stores information as long as that information is being used to complete a certain task. Working memory reflects systems in the temporo-parietal and frontal lobes (Baddeley, 2001; Baddeley & Hitch, 1974). On the other hand, riding a bicycle is a skill improved via repeated practice and does not require explicit retrieval. This would be an example of nondeclarative memory where sensory inputs are directly sent to the cerebellum and the motor cortex, without conscious recollection (Squire, 2009). The current studies focus exclusively on another type of memory, called episodic memory.

Episodic memory refers to the storage of the *what*, *where*, and *when* surrounding a specific event, i.e. its context. It is the memory of the content of a prior event and the context in which it was experienced (Baddeley, 2001; Moscovitch et al., 2006). For instance, the memory of celebrating a particular friend's birthday in a London restaurant last year would be classified as an episodic memory. The classic definitions of episodic memory mention that it entails a feeling of intimacy with the remembered event, involves the ability to mentally reconstruct an episode, is centred on the person who is remembering, and is a phenomenon recognized by everyone but difficult to explain verbally (reviewed by Tulving, 1987). Despite all those seemingly human characteristics, research has shown that other animals, such as the scrub jay, are also able to retrieve contextual information about an event and use it to make new decisions (Clayton, Griffiths, Emery, & Dickinson, 2001). This offers further support for the importance of episodic memory in most of our actions.

There is more than one way of assessing episodic memory performance. Free recall, for instance, requires participants to name/describe as many items as possible from the encoding phase (e.g. Kopelman & Stanhope, 1998; Whythe & Smith, 1997). Recognition tasks, on the other hand, are done by re-presenting items to participants and asking them to identify the ones that were and the ones that were not presented before (e.g. Koen & Yonelinas, 2014; Prull, Dawes, Martin III, Rosenberg, & Light, 2006). This thesis used recognition memory tasks because they allow for the distinction between recollection and familiarity and lend themselves well to neuroimaging studies, as explained in the next paragraph. Recognition memory can be thought of as a continuum of memory strength with a determined threshold. That is, stimuli presented during encoding and test phases will have different degrees of familiarity to participants. Items that fall above each participant's threshold will be judged as old ("hits") and items that fall below the threshold will be classified as new ("misses") (Squire, Wixted, & Clark, 2007). The same happens with items presented only during the test phase, with some receiving a new judgement ("correct rejections"), and some being judged as old ("false alarms") (Snodgrass & Corwin, 1988; Wixted, 2007). Each participant's threshold is different and will define how liberal or conservative they are in their judgments, which can be measured by the response bias (Snodgrass & Corwin, 1988).

In this thesis, however, as mentioned before, a different interpretation is adopted, where recognition memory is based on two processes, called recollection and familiarity (Yonelinas, 2002). The first one happens when the participant recalls specific details about his first encounter with that particular event, such as the time, place, context, etc. The second type of memory processing happens when the person identifies the event as "old" based on a general feeling of having encountered it before but without recalling additional information about the event (Eichenbaum et al., 2007; Migo, Mayes, & Montaldi, 2012; Moscovitch et al., 2006; Squire et al., 2007).

Recollection and familiarity have different characteristics. Familiarity is faster and more automatic than recollection, since less time is needed to simply recognize something as old than to recollect specific information about it (reviewed by Eichenbaum et al., 2007; Yonelinas, 2002). As a consequence, judgement errors based on familiarity are usually more frequent than the ones based on recollection (Yonelinas, 2002). In laboratory studies, different manipulations affect recollection and familiarity in distinct ways. In a review by Yonelinas (2002), a deeper level of processing during encoding is shown to lead to larger recollection with little effect on familiarity. Similarly, the inclusion of a second, distracting task during encoding or retrieval impairs recollection more than it does familiarity. On the other hand, an increase in the number or duration of stimuli increases both recollection and familiarity, while a longer study-test delay decreases them.

Neuroimaging studies offer support for the idea that recollection and familiarity are not a continuum of memory strength or confidence, but two separate memory mechanisms, since they usually show activity in different regions (Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Eichenbaum et al., 2007; Paller & Wagner, 2002). For example, Yonelinas, Otten, Shaw, and Rugg (2005) compared brain activity between items participants judged as recollected versus highly familiar. The results showed different brain networks activated by the two processes, including activity in the hippocampus for recollection but not high familiarity. This finding has been replicated in other studies and meta-analyses (Montaldi, Spencer, Roberts, & Mayes, 2006; Skinner & Fernandes, 2007) (but see Wais, Squire, & Wixted, 2009). Evidence reviewed from amnesic patients and fMRI suggests that recollection is dependent on the hippocampus and parahippocampal cortex, while familiarity can be achieved via the surrounding regions like the perirhinal cortex (Diana, Yonelinas, & Ranganath, 2007; Yonelinas, 2002; Yonelinas, Aly, Wang, & Koen, 2010). Additionally, activity in the parietal cortex is also markedly different between recollection and familiarity, with the first seen in the posterior part of the region and the latter in the intraparietal sulcus (Johnson, Suzuki, & Rugg, 2013; Vilberg & Rugg, 2008). Many event-related potential (ERP) studies also support the idea that familiarity and recollection are temporally, topographically and functionally distinct. The ERP literature will be reviewed in the following section.

Neural correlates of memory processing

The subsequent memory effect

An important question in the field of episodic memory is what makes some events more memorable than others. Identifying the brain mechanisms that influence how well each event will be retrieved in the future is a crucial way of investigating that question (Paller & Wagner, 2002). The use of neuroimaging techniques offers important insights into this matter because it allows the separation of encoding and retrieval processes, and the isolation of encoding-related versus other cognitive processes that operate while events are initially encountered (D. C. Park & Gutchess, 2005; Rugg & Morcom, 2005). The brain mechanisms supporting encoding can be studied via the Subsequent Memory Effect (or *D*ifference due to *M*emory, Dm, effect), defined by Paller, Kutas, and Mayes (1987) as the difference between activity elicited during a study phase by items later remembered and later forgotten. This approach has been successfully used in fMRI (e.g. Vogelsang, Bonnici, Bergstrom, Ranganath, & Simons, 2016), intracranial EEG (e.g. Long, Burke, & Kahana, 2014), magnetencephalography (e.g. Osipova et al., 2006) and scalp EEG studies, described below.

The 1980s saw the first studies to use ERPs to evaluate the Dm effect. For instance, Paller et al. (1987) and Sanquist, Rohrbaugh, Syndulko, and Lindsley (1980) asked participants to make semantic and lexical decisions about words presented one at a time, which was followed by a surprise memory task. In the two studies, later remembered words were found to elicit more positive-going activity during encoding than later forgotten words. This activity was present at central sites between 400 and 800ms after word onset, and was named, by the authors (Paller et al., 1987) as the late positive complex. During that decade, research also suggested that the Dm effect was only present when information was incidentally encoded (Fabiani, Karis, & Donchin, 1986).

Since then, however, studies have shown that latency and topography of Dm effects are not always the same and can be influenced by a number of manipulations (Rugg & Allan, 2000). For example, Guo, Voss, and Paller (2004) compared Dm effects for facial stimuli and for names. Their results showed positive-going Dm effects for faces between 400 and 800ms after item onset at centro-parietal areas. In contrast, Dm effects for names were found to be negative-going in an earlier time window and at fronto-central regions, demonstrating that the effects are dependent on the type of stimuli being remembered. Similarly, Otten, Sveen, and Quayle (2007) found that words elicit Dm effects that are largest at frontal sites, related to semantic processing (Friedman & Johnson Jr, 2000; Paller & Wagner, 2002), whereas nonwords (pronounceable but meaningless strings of letters) elicit a widespread negativity. Other studies have found that Dm effects depend on distinctiveness of the stimuli, with low-frequency words eliciting a larger positive Dm effect than high-frequency words (Fernandez et al., 1998; Guo, Zhu, Ding, Fan, & Paller, 2004). This result supports the idea that different stimulus material leads to qualitatively different encoding mechanisms. Interestingly, even when the stimuli to be remembered are the same, the type of encoding task influences Dm effects, since words encoded in a deep semantic task elicit different activities than words encoded in a shallow alphabetic task. More specifically, deep encoding leads to a frontally distributed positivity, whereas shallow encoding elicits a negative-going activity at central sites (Guo, Zhu, et al., 2004).

Additionally, the unitization of information to create a new concept can elicit a parietal Dm effect not present when pieces of information are encoded individually (Kamp, Bader, & Mecklinger, 2017). In summary, the study of Dm effects sheds light on the variety of cortical mechanisms that support episodic memory, as detailed next.

In terms of familiarity and recollection, Dm effects have been measured using the remember/know procedure or source memory tasks. For example Duarte, Ranganath, Winward, Hayward, and Knight (2004) presented images of objects that were judged according to either animacy or manipulability. A remember/know test followed. Results showed Dm effects only for recollected trials at frontal sites between 450-600ms, with no difference between know and missed trials. Similarly, Friedman and Trott (2000) tested participants' memory for words seen in two different lists during encoding. Again, results showed positive activities between 410-600ms for recollected items only. These findings support the idea that recollection and familiarity have distinct cortical correlates and are separate processes.

Paller and colleagues did a series of studies about familiarity and recollection using source tasks. In one of them, Guo, Duan, Li, and Paller (2006) presented participants with characters framed by one of two geometric shapes and tested memory for the item and the source. Both item and source memory elicited a frontally distributed positive-going Dm effect, with no statistical difference between them. The authors suggested that the encoding activity reflects processing of the pair as one, rather than separate mechanisms for item and source. Similarly, Guo, Voss & Paller (2004) found no differences between Dm effects for face-name associations when compared to face-only memory, suggesting that those effects reflect the visual processing of the item without specific processing of source. In contrast, Yovel and Paller (2004) found a positive Dm effect at central sites between 600-800ms that was larger for face-occupation associations than for face-only or no-face responses, while the latter two did not differ from one another. The authors propose familiarity is a weaker form of recollection, achieved when only part of the recollection-related cortical substrate is activated.

To sum up, Dm effects have been widely used to investigate how different events are encoded into memory. The larger positive activity for later remembered items on centro-frontal sites seems to be fairly consistent in the literature, indicating deeper information processing. Shallow processing and the appearance of unfamiliar stimuli seem to elicit a negative-going activity at central sites. However, the activities underlying familiarity and recollection show mixed results. This thesis expands the literature on Dm effects by investigating how different types of information, in particular emotional valence, influence the formation of memory in different age groups. This thesis also studies Dm effects that occur prior to the presentation of the to-be-remembered item, since this activity has recently been shown to predict later memory performance. This literature will be reviewed next.

Activity before stimulus onset

Otten and Rugg (2001) found an interesting pattern when investigating the Dm effects for different task types. The positive-going activity seen for the deeper encoding task and the negative-going activity seen for the shallower task showed onsets in an earlier time window than expected. The authors hypothesised that this had been caused by the presence of prestimulus cues that indicated the type of the upcoming task, and that memory encoding was supported by cognitive processes occurring before stimulus presentation. To properly test this idea, Otten, Quayle, Akram, Ditewig, and Rugg (2006) conducted two experiments in which the items in the encoding task were preceded by informative cues. In experiment 1, the cues indicated whether the decision about the upcoming word should be semantic or orthographic. In experiment 2, the cues indicated if the word would be presented in visual or auditory format. The results showed that, in the two experiments, later remembered words elicited a more positive-going activity at frontal sites than later forgotten words, which is in accordance with the literature reviewed earlier. More importantly, activity following cue but before word onset also predicted later memory. This activity was more negative-going for words that were later remembered, and strongest at frontal scalp sites just before the onset of the word. The authors explained the findings by saying that prestimulus Dm effects represent the adoption of a "task set", i.e. an orientation in which additional cognitive resources are allocated to the task in hand.

Surprisingly, in Otten et al. (2006), prestimulus Dm effects were not present for the orthographic trials in experiment 1 or for the auditory trials in experiment 2. The absence of prestimulus Dm effects for the orthographic condition in that study suggests that it does not simply reflect a general temporal anticipation, but rather a semantic preparation for a future event (Otten, Quayle, & Puvaneswaran, 2010). To further investigate the reasons for this absence of prestimulus Dm effects before the auditory words, Otten et al. (2010) conducted a new experiment. This time, visual and auditory words were preceded by visual and auditory cues, respectively. This was done so that the presentation modality was held constant and participants did not have to use their anticipatory cognitive resources to shift between auditory and visual modes. Results showed that the frontal negative-going prestimulus Dm effect occurred in both conditions starting at 750ms after cue onset. The presence of prestimulus Dm effects for both the visual and the auditory conditions led to the conclusion that the role of this activity in encoding is not restricted to the visual modality.

When combined with the results from Otten et al. (2006), the findings from Otten et al. (2010) also suggest that prestimulus activity requires the allocation of cognitive resources, which are not available when participants need to switch between auditory and visual stimulus modality. In order to test the hypothesis that prestimulus Dm effects require availability of cognitive resources, Galli, Gebert, and Otten (2013) manipulated the availability of resources by asking participant to complete an easy or a difficult judgment about the cues that preceded the words. As predicted, prestimulus Dm effects were found for both visual and auditory trials, but only in the easy condition. These results support the idea that prestimulus activity represents active preparation for the upcoming event, since, in the difficult condition, participants' attention was divided, not leaving enough cognitive resources for the preparatory activity.

If the amount of available cognitive resources modulates the presence of prestimulus Dm effects, an interesting question is whether participants are able to voluntarily control the allocation of such resources. To test if this preparation is under voluntary control, Gruber and Otten (2010) conducted a new study, in which the prestimulus cues indicated how much monetary reward (low or high) the participant would win if the following word was remembered in a later memory task. With this design, the authors expected that participants would be more motivated to encode the high-value words than the other ones and, therefore, to voluntarily allocate more prestimulus resources to high-value trials. As expected, only the high-value condition showed differences in brain activity preceding words that were later remembered and later forgotten. This suggests that prestimulus preparation is, indeed, under voluntary control. Importantly, the type of activity seen in this study was different from the previously mentioned ones, since it took the form of a widely-distributed positive-going deflection beginning around 300ms after cue onset. The authors acknowledged this fact and proposed that there are multiple ways of preparing for an upcoming stimulus, with different ERP topographies. It is possible that semantic preparation is reflected in the anterior negative-going activity, and motivation-related activity is evidenced by a widespread positivity.

Prestimulus Dm effects have also been studied using techniques other than ERPs. In the EEG oscillations domain, theta activity before stimulus onset is enhanced for items that are later remembered compared to items later forgotten when measured via magnetoencephalography (MEG) (Guderian, Schott, Richardson-Klavehn, & Duzel, 2009), scalp-recorded EEG (Gruber, Waltrous, Ekstrom, Ranganath, & Otten, 2013) and intracranial EEG in the hippocampus (Fell et al., 2011; Merkow, Burke, Stein, &

Kahana, 2014). In terms of fMRI, larger prestimulus activity following high-reward cues in the entorhinal cortex and the ventral tegmental area correlated with higher performance on a later memory recognition task during encoding (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006). Similarly, during an incidental encoding task followed by remember/know decisions, activity in the hippocampus was larger for later remembered items compared to known and forgotten items (H. Park & Rugg, 2010). Additionally, some of the above-mentioned studies concluded that novel or rewarding stimuli activate the mesolimbic dopaminergic system that relates to a modulation of preparatory activity (Adcock et al., 2006; Gruber, Gelman, & Ranganath, 2014; Gruber et al., 2013; H. Park & Rugg, 2010). Recently, the study of prestimulus activity has been linked to educational and learning environments. For instance, Gruber et al. (2014) used questions that participants were or were not curious about as cues preceding facial photographs. Their results showed that one's state of curiosity increases the dopaminergic modulation of the hippocampal activity that happens before an item is encountered, enhancing memory performance. All these studies exemplify that, although relatively recent, the finding that prestimulus encoding activity predicts later memory has gained a lot of interest in the literature and has been shown to be a consistent effect. It is also evident that none of these studies looked at how prestimulus activity changes across the lifespan. This is a reasonable question since post-stimulus encoding activity and retrieval-related activity have been found to differ between younger and older adults (see discussion later on in this chapter). Similarly, only two studies have (Galli, Griffiths, & Otten, 2012; Galli, Wolpe, and Otten (2011)) have investigated prestimulus activity in relation to emotions. In this thesis, ERPs are used to investigate the effects of ageing on prestimulus encoding-related activity for emotional information.

Old/new effects

It is clear from the literature reviewed in the previous section that neural activity during encoding is able to predict later memory. However, memory is also greatly affected by what happens during retrieval. A widely-used way of investigating the neural correlates of retrieval is through old/new effects. These effects have been used since the 1980s and are measured by the difference between brain activity elicited by correctly retrieved old items and new items correctly identified as such (Rugg, 1995). In terms of ERPs, there are at least three consistently found old/new effects: an early mid-frontal effect, a later left-parietal effect, and an even later right-frontal effect.

The first old/new effect is called the "mid-frontal effect" and takes the form of a positive-going activity at mid-frontal scalp sites between 300-500ms after stimulus onset (Curran, 2000). The second one is the "left-parietal effect", which is composed of positive-going activity at left-parietal sites between 500-800ms after stimulus onset (Woodruff, Hayama, & Rugg, 2006). The existence of dissociable mid-frontal and left-parietal effects offers strong support for the dual-process theory of memory (explained before): the mid-frontal effect seems to be related to familiarity, and the left-parietal effect to recollection (Duarte et al., 2004; Friedman & Johnson Jr, 2000; Moscovitch et al., 2006). For instance, Tsivilis et al. (2015) tested participants' memories for items that had been learned a longer (four weeks) or shorter (five minutes) time before. The recent memories showed classic mid-frontal and left-parietal effects. However, the remote items elicited only the familiarity effect. This result was accompanied by behavioural findings supporting the view that old judgments to remote memories had been based on familiarity processes. Those findings support the idea that familiarity and recollection, and their neural correlates, are qualitatively different recognition processes. Recognition memory studies have found the mid-frontal effect for "know" and for "remember" responses, and the left-parietal effect only for the latter (Curran, 2004).

Studies that use lures have supported the relationship between the mid-frontal effect and familiarity. In those studies, correctly retrieved old items show similar mid-frontal, but stronger left-parietal, effects to lures given an "old" judgment. This suggests that items that look familiar (both correct and incorrect) are able to elicit the mid-frontal effect, and only the ones that also elicit the left-parietal effect will be rightly identified as old (Curran, 2000; Curran & Cleary, 2003). However, Paller and colleagues propose that the mid-frontal effect is not always a correlate of familiarity. These authors argue that it can be related to conceptual priming. The phenomenon of priming happens when behaviour is unconsciously changed due to something experienced before, i.e. participants may show the mid-frontal effect to lures simply because they have been previously primed with similar items (Paller, Lucas, & Voss, 2012; Paller, Voss, & Boehm, 2007). Using famous faces, the same authors claim that very similar mid-frontal effects are found when comparing pure familiarity effects with effects elicited by famous faces that were previously primed with biographical information (Voss & Paller, 2006). Additionally, familiarity has been linked to a weaker left-parietal effect instead of a distinct mid-frontal effect (Yovel & Paller, 2004). This view has been criticized by Rugg and Curran (2007), who review studies that used abstract or completely novel stimuli during encoding (i.e. no possibility of priming) and showed a robust mid-frontal effect correlated with familiarity levels. Thus, the neural correlates of familiarity are still not defined and new studies are necessary, perhaps adding behavioural measures of implicit priming to recognition memory paradigms in order to differentiate between familiarity and conceptual priming (Paller et al., 2007).

The role of the left-parietal effect is also not fully defined, although it is widely thought to be a graded index of recollection, i.e. the more remembered information, the larger the effect (Paller & Kutas, 1992; Rugg, 1995). Wilding (2000), for example, asked participants to memorise words presented in two different but concomitant sources – the sex of the speaker and which type of judgment was made following the word presentation. His findings showed the left-parietal effect to be larger for the trials where both sources were remembered, compared to when only one was retrieved, and larger when one source was remembered compared to when no source was remembered. More recently, Murray, Howie, and Donaldson (2015) used an objective source memory task, in which participants had to indicate where, in a circle, a previously studied item had occurred. The degree of error between the actual location and the one retrieved by participants was correlated with the strength of the left-parietal effect. Results showed that there was no left-parietal effect when the error was higher than 90 degrees, but that it was present for the more precise judgments in a positive correlation with how close the response was from the original position. These findings support the role of the left-parietal effect in recollection mechanisms, since the objectively measured memory accuracy correlated with the strength of the effect. However, not all evidence points to the left-parietal effect being an index of recollection. At least with facial stimuli, a high performance on recollection tasks can be achieved without the presence of left-parietal activation (MacKenzie & Donaldson, 2007, 2009). Instead, these studies found a positive-going anteriorly-distributed old/new effect, which suggests that the neural correlates of recollection can be different in distinct circumstances.

The final old/new effect is called the “right-frontal effect” and is usually formed of a sustained positivity on right-frontal scalp sites beginning around 800ms after stimulus onset (Jaeger & Parente, 2008). One line of evidence supports the idea that this effect is related to verification processes and control functions (Windmann, Urbach, & Kutas, 2002), being important for deciding how to manipulate the products of retrieval. For example, the effect has been shown to be larger when retrieved information should be kept in mind to make a follow-up decision (Jaeger & Parente, 2008). Interestingly, the right-frontal effect does not necessarily correlate with successful recollection, having been found to be sometimes larger for incorrect judgments (Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999). Another line of evidence suggests that, rather than being a monitoring system for retrieved information, the right-frontal effect is related to decision-making. For example Hayama, Johnson, and Rugg (2008) manipulated whether the products of retrieval were necessary for further decisions after the initial old/new judgment. In one of the conditions, participants had to recall the encoding source of an item, while in the other condition they should make an unrelated judgment about the item itself (e.g. animacy). If the right-frontal effect was related only to evaluation of the retrieved information, it should not be present for the second condition. The findings showed equal right-frontal effects for both conditions, suggesting that the effect is related to decision-making. In the same paper, the authors describe a second study in which the animacy decision should be given for the old or the new item depending on the condition. Again, the right-frontal effect was present for both conditions, supporting the idea that it does not necessarily relate to recollection.

In summary, old/new effects during retrieval are a robust way of investigating the neural correlates of memory. In this thesis, old/new effects are used to investigate how the different correlates of recognition memory are affected by the emotional valence of items and by the age of the participants. Vast evidence suggests that the mid-frontal and the left-parietal effects are qualitatively different mechanisms of recognition memory, with most authors considering them to be indices for familiarity and recollection, respectively. The role of the right-frontal effect is still being debated. More research is needed to conclude if it is related to recognition or a broader decision-making mechanism.

Episodic memory and ageing

Ageing effects on cognition have been empirically studied since the 1920s and a lot has been discovered in these past 100 years (Salthouse, 1996). Although influenced by individual differences such as education level and visual/auditory acuity (reviewed by Drag & Bieliauskas, 2010), general structural and physiological alterations in the brain are known to occur with ageing. Examples include changes in the blood supply (Keuker, Luiten, & Fuchs, 2003), expression of proteins by neurons (Merril, Roberts, & Tuszynski, 2000), thickness of cortical layers, especially in the prefrontal lobe (Salat et al., 2004), and morphology of dendrites (Burke & Barnes, 2006). Studies in cognitive neuroscience are trying to relate these neuronal and physiological changes to age-related cognitive and behavioural differences. This is fundamental to the future development of ways of helping older adults to have a better memory (Hedden & Gabrieli, 2004).

The large number of cognitive domains that seem to be impaired by ageing makes it difficult to come up with a theory that explains all of them. It could be that impairments are caused by several factors or by a small number of factors that have broad consequences (D. C. Park, Polk, Mikels, Taylor, & Marshuetz, 2001; Salthouse, 1996). Another issue is to determine if the deficits are independent from each other or if the impairment in one brings about the impairment in another (Salthouse, 1996). In this line, Head, Rodrigue, Kennedy, and Raz (2008) tested different predictive models of episodic memory decline with ageing and found that, when removing the influence of working memory, speed of processing and inhibitory control, age had no effect on memory performance. This highlights the complexity of cognitive ageing and the need to use different tasks and instruments for its evaluation.

The main aim of studies on cognitive ageing is to investigate possible systematic age-related differences in the neural correlates of particular cognitive processes (Rugg & Morcom, 2005). The first ageing study to use neuroimaging techniques was by Grady et al. (1995). These authors measured cerebral blood flow of younger and older participants during encoding and recognition of facial stimuli. Younger participants outperformed the older adults. Neuroimaging results showed that, during encoding, younger people had larger activity in the left prefrontal cortex and medial temporal areas than older participants. During retrieval, younger adults had larger activity in right parietal and occipital cortices but did not differ from older adults in right prefrontal activity. These findings were replicated in other studies and their importance was to show that the ageing brain does not simply generally decline in activity, but that younger and older adults show qualitatively different patterns of activity during distinct memory processing (D. C. Park & Gutchess, 2005).

An early review (Balota, Dolan, & Duchek, 2000) presented the main theories that tried to explain the differences observed between younger and older adults' brains. One theory claims that ageing brings a diminished speed of processing, therefore, any memory impairments would be caused by the information being more slowly processed by older than younger adults (Salthouse, 1996). This idea is supported by neuroimaging studies showing that memory-related brain activity is qualitatively similar but temporally delayed in older adults – who also show lower performance – when compared to younger adults (Morcom & Rugg, 2004; Zanto, Toy, & Gazzaley, 2010). However, findings showing that ageing differently influences tasks that do not require fast processing of information challenge this view and suggest that other mechanisms must be behind cognitive ageing (Luo & Craik, 2008).

Another theory suggests that older adults have fewer cognitive resources during encoding and retrieval, causing lower performance in memory tasks (Balota et al., 2000). This idea gains support from studies about divided attention, in which participants are required to perform a second unrelated task during encoding or retrieval. These studies have shown that memory performance in the main task is reduced when participants' attentional resources are shared with a distracting task. In younger and in older adults, the effects of divided attention are more severe when the distracting task is conducted during encoding (Fernandes, Craik, Bialystok, & Kreuger, 2007; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005). However, older adults are also affected when the second task happens during retrieval, suggesting that this age group has an overall limitation of cognitive resources during both moments of the memory processing (Naveh-Benjamin et al., 2005). One interesting piece of research (Castel & Craik, 2003) tested the effects of ageing and of divided attention by comparing memory performance in younger adults under divided attention conditions with that of younger and older adults under full attention conditions. Younger adults under full attention conditions performed better than the other two groups, who did not differ from each other, suggesting that ageing and divided attention have similar effects. Nevertheless, the theory that lower memory in older adults is caused by the lack of cognitive resources has been criticized for being too vague and not specifying the exact types of decreased cognitive resources (Luo & Craik, 2008; Salthouse, 1996).

Although these two theories are still considered nowadays (Drag & Bieliauskas, 2010; Luo & Craik, 2008), more recent models have been proposed to explain ageing deficits in episodic memory and other cognitive domains, such as the Scaffolding Theory of Aging and Cognition (STAC, D. C. Park & Reuter-Lorenz, 2009). According to this model, the shrinkage of brain structures, thinning of white matter and other neurological alterations in the ageing brain are naturally responded to with functional changes in which the brain recruits additional circuitry. More specifically, the model proposes that structures that have defined and focused roles will not engage in scaffolding, such as the ventral visual cortex with its role in the computation of perceptual properties of visual stimuli. In fact, those structures will have their roles compensated for by more general structures, such as the prefrontal cortex but also other regions such as parietal, mediotemporal and occipital cortices (D. C. Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Park, 2010). Interestingly, the authors suggest that this "scaffolding" mechanism happens in people of all ages, but, for younger adults, it is used when facing novel and challenging situations, whereas older adults need it for more mundane and familiar tasks (D. C. Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Park, 2010). An example of this is the additional recruitment of the right dorsolateral prefrontal cortex in younger adults when their left structure is not enough to solve highly demanding visual working memory tasks (Reuter-Lorenz & Cappell, 2008). In older adults, this bilateral activation should be present even in low demanding tasks, in which their performance is also impoverished (D. C. Park & Reuter-Lorenz, 2009).

The STAC model is based on previous models about compensatory mechanisms in the ageing brain. For example, the Hemispheric Asymmetry Reduction in Older Adults (HAROLD) model predicts bilateral activity in older adults' prefrontal cortices in tasks in which younger adults activate only one hemisphere (Cabeza, 2002). This additional activity works as a compensatory mechanism and has been shown to positively correlate with memory performance (Cabeza, Anderson, Locantore, & McIntosh, 2002). Another model that mentions compensatory recruitment of brain regions is the Compensation-Related Utilisation of Neural Circuits Hypothesis (CRUNCH, Reuter-Lorenz & Cappell, 2008). This model predicts that the activity of additional areas is beneficial only under low-demanding conditions, since beyond a certain difficulty level, the ageing brain runs out of reserve resources and performance begins to decline in comparison with younger adults. This model is somewhat more generic than HAROLD, since it predicts overactivity outside of the prefrontal cortex and not necessarily contralateral (Berlingeri, Danelli, Bottini, Sberma, & Paulesu, 2013).

Another pattern usually seen in the ageing literature is increased frontal activity in older adults in compensation for decreased efficiency of perceptual regions of the brain, which receives the name of Posterior-Anterior Shift in Aging (PASA) and positively correlates with memory performance (Davis, Dennis, Daselaar, Fleck, & Cabeza, 2007). Importantly, some authors argue that these findings reflect that older adults' pattern of brain activity is dedifferentiated, i.e. shows less specificity in which brain areas are recruited for each task, which would lead to a general age-related decline in cognitive efficiency (D. C. Park et al. 2001; Reuter-Lorenz & Park, 2010). This pattern can also be found in studies in which the two age groups show the same performance, but brain activity is larger or more diffused for older adults (Grady, 2008).

One thing in common between the hypotheses reviewed by Balota et al. (2000) and the models proposed by D. C. Park and Reuter-Lorenz (2009) and Cabeza (2002) is the acknowledgment that not all types of cognitive skills decline equally with ageing. For instance, a vast number of studies suggests that inhibition mechanisms, attention, problem-solving abilities, and spatial cognition are reduced in older adults (e.g. Andrés, Guerrini, Phillips, & Perfect, 2008; Klencklen, Després, & Dufour, 2012; Zanto & Gazzaley, 2014), whereas verbal abilities, world knowledge and emotion regulation skills are not affected or even improve with age (e.g. D.C. Park et al., 2002; Urry & Gross, 2010). More relevant for this thesis is the fact that not all types of memory decline equally with ageing, as shown in different review papers and in population-based longitudinal studies (Grady & Craik, 2000; Hedden & Gabrieli, 2004; Nilsson, 2003; D. C. Park & Gutchess, 2005; D. C. Park et al., 2002; Ronnlund, Nyberg, Backman, & Nilsson, 2005). For instance, declines in working memory in older adults are seen with a variety of stimuli and offer support for the compensatory models proposed above, with older participants showing additional recruitment of brain and cortical regions (e.g. Belham et al., 2013; Schneider-Garces et al., 2010). Semantic memory, on the other hand, measured by the retrieval of general knowledge and of famous public events, is relatively stable in ageing and does not show differences in brain activation between younger and older participants (e.g. Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Maguire & Frith, 2003; Piolino, Desgranges, Benali, & Eustache, 2002). Regarding episodic memory, although it shows strong age-related declines, the types of task and information to be retrieved also influence older adults' performance. Relevant for this thesis are the findings that recollection is more impaired than familiarity, and that source recall is more impaired than item recall (Cansino, 2009; Drag & Bieliauskas, 2010; Friedman, Chastelaine, Nessler, & Malcolm, 2010; Luo & Craik, 2008; Yonelinas, 2002). These findings will be reviewed next.

Anecdotally, it is fair to say that older adults are known for asking the same question repeatedly. Jacoby (1999) explains this by assuming that familiarity is preserved in ageing whereas recollection is impacted. Every time a question is asked, it becomes more familiar, however the circumstances in which the questioning happened, its answer, or even the mere fact that it has been asked are not recollected, causing older adults to simply feel like asking it again. As reviewed by Yonelinas (2002), many studies have shown the effects of ageing to be more severe on recollection than familiarity, and that the ones that do not, are probably due to a ceiling effect in the "know" responses. The reduced ageing impairment in familiarity has been demonstrated with facial stimuli (e.g. Bastin & Van der Linden, 2003), words (e.g. Anderson et al., 2008) and images (e.g. Howard, Bessette-Symons, Zhang, & Hoyer, 2006).

Nevertheless, it is crucial to point out that these results depend on the type of task in use. Prull et al. (2006) compared younger and older adults' performance in three different tasks: remember/know, receiver operating characteristic (ROC), and process dissociation (PD). In ROC, participants use a confidence scale to judge the items presented in the memory task. In PD, participants study items in two conditions and answer two versions of a memory task. In the inclusion task, they indicate all items that were studied irrespective of the condition. In the exclusion task, they identify only the items that were presented in one of the two conditions. The results showed that recollection was impaired in older adults in all three tasks, and that familiarity was impaired in remember/know and ROC but preserved in PD. The authors suggested that, because remember/know and ROC require a direct report of the conscious experience of familiarity, older adults could be impaired in their ability to assess this phenomenological experience. However, a meta-analysis (Koen & Yonelinas, 2014) looked at 39 published papers that used remember/know, ROC or PD to assess recollection and familiarity in older adults. The authors found that recollection was significantly impaired in older adults regardless of the method used, and that familiarity was only impaired in the remember/know task. This may be due to the remember/know instructions being more complicated to grasp, since they involve subjective decisions, which may lead to different strategies being adopted by the two age groups (Koen & Yonelinas, 2014).

The use of source memory tasks seems to bring out more consistent results. Both an early (Spencer & Raz, 1995) and a more recent (Old & Naveh-Benjamin, 2008) meta-analysis show that age-related differences are significantly larger for contextual and associative information than for the item itself. This may happen because older adults have more difficulty in binding different pieces of information into a coherent memory representation, i.e. they remember particular features of an event, but do not form a complex memory with them (Chalfonte & Johnson, 1996). Naveh-Benjamin (2000) worked with this possibility to create the Associative Deficit Hypothesis (ADH). This hypothesis predicts that older adults are able to remember different aspects of an event (e.g. what, when, where) but not the link between them. This would be caused by older adults using none or very simplistic strategies to associate event details (Naveh-Benjamin, 2000).

Supporting this idea are studies that tested the association between semantically-related items and found a reduced age-related deficit in source memory, suggesting that the pre-existing associations between those stimuli compensate for the lack of effortful encoding strategies by older adults (Badham, Estes, & Maylor, 2012). Also in this line, some studies have investigated if the effects of ageing on source memory are softened by specifically teaching cognitive binding strategies to older adults. For instance, Bastin et al. (2013) instructed younger and older participants to either imagine the to-be-remembered object in a specific colour (unitization) or to imagine it alongside another object of that colour. Memory for the colour was tested a week later and results showed that the use of unitization eliminated age-related differences in performance. Another example is Naveh-Benjamin, Brav, and Levy (2007)`s study that tested younger and older participants in three experimental conditions. The first group was simply instructed to memorize word pairs. The second group was told to memorize the pairs by creating a sentence with the words. The final group was also told to create sentences and to, additionally, think back to those sentences when answering the source memory task. The results showed that the largest age-related decline in source memory was seen in the first group, being reduced in the second group and almost eliminated in the third group. These findings support the idea that older adults do not use self-initiated encoding or retrieval strategies (Naveh-Benjamin, 2000), but can do so effectively when instructed. As a summary, older adults show (almost) preserved item memory – remembering the central piece of information – but impaired source memory – binding between the item and the other contextual features of a given event (Chalfonte & Johnson, 1996). This impairment, nevertheless, can be overcome by the use of cognitive encoding strategies, such as unitization.

In conclusion, ageing leads to unequal decline in different cognitive domains, including memory performance. The strongest decline is seen in episodic memory, although the types of task and to-be-remembered information play an important mediatory role. Additionally, some age-related differences can be overcome by teaching older adults specific encoding or retrieval strategies. As mentioned before, the use of neuroimaging techniques can improve the understanding of how ageing affects encoding and retrieval and, in consequence, help the development of techniques and strategies to help older adults to overcome eventual mnemonic difficulties (Hedden & Gabrieli, 2004).

Neuroimaging studies on ageing and memory

Encoding-related activity

With respect to encoding in ageing, Friedman, Ritter, and Snodgrass (1996) measured Dm effects in younger and older adults during shallow (alphabetic) and deeper (semantic) encoding tasks. Their results showed that, for both types of task, younger adults showed a larger positive-going Dm effect at parietal sites, whereas older adults did not show reliable Dm effects. Since there were no differences in performance between the groups, the authors proposed that either the memory task used (cued recall) was not powerful enough to show age-related differences in performance, or the Dm effects in older adults were delayed in relation to younger adults' and were not captured by the conducted analyses. In another study, Friedman and Trott (2000) asked younger and older participants to memorize words and the list in which they were presented during encoding. Results showed that the two age groups had similar performance, and both showed a widespread positive-going Dm effect beginning at around 300ms and lasting for the entire epoch. In younger adults, the activity for recollected items was more positive-going than the activity for familiar items. In older adults, activity for recollected and familiar items did not differ from each other (measured with the remember/know task). The authors explained this finding by proposing that older adults encode all items in the same shallow manner. Their memory will, thus, be more based on familiarity than on recollection. Additionally, because the items were not encoded with different strengths, older adults will have greater difficulty in differentiating the specific details of the episodes during retrieval, increasing their false alarm rate (Friedman & Trott, 2000). The authors also suggest that the general presence of Dm effects in this study was caused by the intentionality of the encoding task, whereas in Friedman et al. (1996), an incidental task was used. This means that older adults would only deploy encoding strategies if instructed to do so. However, this suggestion does not explain the high level of performance of Friedman et al. (1996)'s older adults.

The hypothesis that older adults only deploy encoding strategies when instructed was also not supported by later studies. Téllez-Alanís and Cansino (2004) directly compared intentional and incidental tasks and found older adults to perform worse han younger adults. Results also revealed widespread positive-going Dm effects for the two age groups in both tasks, suggesting that previous conflicting results were not simply caused by methodological particularities. These authors propose that the findings from Friedman et al. (1996) were confounded by stimuli being presented more than once during encoding, although they did not expand on this idea. Gutchess, Ieuji, and Federmeier (2007) also tested encoding of younger and older adults who incidentally encoded complex visual scenes that were later mixed with lures in a recognition memory task including confidence judgments. No differences were seen in performance or on Dm effects for the two groups. Gutchess, Ieuji, et al. (2007) conclude that encoding-related processes, as measured by Dm effects, seem to be preserved in older adults. In addition to the initial Friedman et al. (1996) paper, another study also failed to find Dm effects in older adults while showing strong effects in younger participants (Kamp & Zimmer, 2015). In this study, older adults performed worse than younger adults, but no direct comparison between the ERP data of the age groups was done, so it is not possible to draw conclusions about age-related differences in brain activity.

In summary, the literature provides mixed results about encoding effects in older adults, with proposals that ERP activity is delayed, absent or equally large when compared to younger adults. fMRI studies have suggested that age-related differences in brain activity may actually be due to the variation in performance of the older population. For example, Duverne, Motamedinia, and Rugg (2009) used a subsequent memory paradigm and found an increase in right-prefrontal activity in ageing leading to a decrease in the asymmetry of the Dm effects. However, this difference was only significant in the low-performing older group. This finding supports the hypothesis that the ageing brain suffers from dedifferentiation and that high-performing older adults are able to maintain the specificity of brain regions seen in youth (Reuter-Lorenz & Park, 2010). In contrast, Rosen et al. (2002) found an increase in right-prefrontal activity for the high-performing older group. This finding, thus, supports the compensatory hypothesis, according to which high-performing adults are able to compensate for the decline in cognitive abilities by activating additional brain areas (Cabeza, 2002). In conclusion, the study of encoding in older adults is not only important to characterize memory across the lifespan but can also help arbitrate between different theories about the functioning of the ageing brain (Friedman, 2003).

Prestimulus activity

Encoding-related prestimulus Dm effects, as explained before in this thesis, have not yet been studied in older adults. Nevertheless, other lines of research hint at how ageing may affect anticipatory mechanisms during encoding. The preparation for an upcoming decision, for example, was studied by Bollinger, Rubens, Masangkay, Kalkstein, and Gazzaley (2011), who asked younger and older participants to memorise different types of stimuli. These were preceded by cues that indicated which type of stimulus would be presented next. The fMRI results showed that a cue predictive of an upcoming facial stimulus modulated younger adults' connectivity between the fusiform face area and the fronto-parietal network, being associated with better performance. This was not the case for older adults, who did not show memory benefits for the cued conditions, suggesting that this group was unable to use the cues to gather cognitive resources that would help encoding. Another study investigated whether older adults would be able to use temporal cues to prepare for the upcoming stimulus (Zanto et al., 2011). Participants were presented with cues that indicated the time remaining for the appearance of the next item, which should be responded to as fast as possible. Results showed that younger adults had a quicker response time when they saw informative cues, whereas older adults did not show any performance difference. In addition, younger participants elicited a contingent negative variation (CNV), a neural marker of expectation during the foreperiod, with slow negative-going activity after the cue increasing as the impending target time approaches (Macar & Vidal, 2004). In contrast, older adults showed a very diminished CNV. Although this study did not tap into memory, it suggests, like the previous one, that ageing is connected with deficits in the utilization of predictive cues to allocate cognitive resources to a particular task.

A different line of research involves the task switching paradigm, where participants need to respond to trials that either repeat or change from the task presented in the previous trial. It is expected that reaction times will be longer when tasks need to be switched as compared to when they are repeatedly presented. Kray, Eppinger, and Mecklinger (2005) altered this paradigm by adding prestimulus cues that indicated the upcoming task and measuring ERP activity during the foreperiod. As expected, younger and older adults were slower to respond when switching tasks, but the effect was larger in the ageing group. In terms of cue-related ERPs, the P300 component, associated with the processing and updating of task-relevant information (Sutton, Braren, Zubin, & John, 1965), showed an overall delayed onset in older adults, which suggests that this age group had more difficulty in using the cues to prepare for a new task.

Another line of research that has used predictive cues to study how younger and older adults prepare for the upcoming stimuli involves inhibition studies. Hammerer, Li, Muller, and Lindenberger (2010) tested participants of different age groups in a task that measured inhibitory control. In this task, twelve squares of different colours were presented in sequence, one at a time. Participants should pay attention and press a button as fast as possible every time they saw a blue square followed by a yellow square. This task involves inhibition because after seeing a blue square, participants prepare themselves for the button press, but must refrain from pressing if the next square is not the yellow one. Older adults were slower than but as accurate as younger adults. ERPs elicited by yellow squares (informative cues) and other colours (non-informative cues) were compared in the period that preceded target onset. The CNV component did not differ between the two age groups. However, in younger adults, the P300 component was only present after the informative cues, whereas older adults did not differentiate between the cues. This suggests that older adults have difficulty in allocating their cognitive resources to relevant information while inhibiting them to irrelevant ones.

Lastly, prestimulus activity during retrieval has also been linked to memory performance via what is called “retrieval orientation”, which is the ability to allocate cognitive resources to match the specific requirements of the retrieval task (Rugg & Wilding, 2000). This effect happens when activity elicited by correctly rejected new items of two different categories differ from each other. The difference is usually maximal on right-central scalp sites and lasts between 300ms and the end of the epoch after retrieval cues have been presented (Robb & Rugg, 2002). In older adults, this effect has the same topography but is weaker, with a later onset and earlier offset, suggesting that they have difficulties in using the cues to differentiate between the different types of upcoming task, resulting in slower and worse memory performance (Morcom & Rugg, 2004).

In conclusion, the recent, but solid, findings in the literature (reviewed in this chapter) showing that brain activity in preparation for encoding influences later memory have expanded the knowledge of memory processing. Because ageing is marked by changes in memory processing and performance, it is of interest to investigate prestimulus activity in older adults. The reviewed findings on the CNV, task switching and retrieval orientation literatures serve as exciting hints at possible age-related differences on anticipatory brain activity.

Retrieval-related activity

A larger number of studies have looked into the electrophysiological correlates of retrieval than encoding in older adults. Friedman et al. (2010) tested participants of different age groups on their recognition memory for symbols. Younger adults outperformed older adults. The results showed similar mid-frontal effects in younger and older participants, but a reduced left-parietal effect in the ageing group. These findings were partially replicated by Angel, Fay, Bouazzaoui, Baudouin, and Isingrini (2010), who found, for highly educated participants, no age-related differences on anterior sites and smaller old/new effects for older adults at parietal sites, though these participants' scalp distribution was bilateral. In that study, younger adults performed better than older adults in the stem-cued test, but the difference was significantly smaller when including only highly educated older participants. In contrast, Duarte, Ranganath, Trujillo, and Knight (2006) reported similar mid-frontal and left-parietal effects in the two age groups in a remember/know test for images, which also revealed lower performance for older adults. A different study found the mid-frontal effect to be reduced in older adults compared to their younger counterparts, when analysing source-hits responses for images of objects (Dulas, Newsome, & Duarte, 2011). In that study, older adults had worse source memory but equivalent item memory when compared to younger participants. After reviewing a series of recognition memory studies, Friedman (2013) concludes that the evidence for an age-related impairment in recollection-based processes is robust, whereas familiarity-related mechanisms show mixed results. He suggests that, perhaps, older adults show an earlier familiarity-related activity that is not captured by the typical time windows used. Other authors have suggested, instead, that ERP effects in older adults usually show a delayed onset (Fabiani & Gratton, 2005).

The right-frontal effect also shows mixed findings in the literature. Trott et al. (1999) tested younger and older adults` source memory for the list in which words had been previously presented. They found that younger adults had better performance and showed regular left-parietal and right-frontal old/new effects, whereas older adults showed a comparable left-parietal effect but no right-frontal effect. The absence of the right-frontal effect in the older participants was used to explain that this population shows deficits in the retrieval of contextual information, fundamental for source judgments. However, as mentioned earlier in this chapter, some authors argue that the right-frontal effect is related to later decision-making and not necessarily to retrieval (Hayama et al., 2008). Thus, it is possible that older adults retrieved the same amount of information as the younger adults but were not able to use that information to distinguish between the lists. Additionally, Mark and Rugg (1998) found results that contradict the previous ones when testing source memory in younger and older adults. The authors found all old/new effects to be indistinguishable between the two age groups. As these authors acknowledge, although they still found age-related differences in behaviour, the different results between theirs and those of Trott et al. (1999) could reflect the general performance of the older group, which was much lower in the latter study. To directly investigate this possibility, Wegesin, Friedman, Varughese, and Stern (2002) repeated Trott et al. (1999)'s procedure but implemented a series of manipulations to boost older adults' performance, such as increasing the exposure time of stimuli and asking participants to engage with the items by rating their likeability. Their results replicated Trott et al. (1999) by showing the absence of the right-frontal effect in older adults, despite enhanced performance. However, this time, the left-parietal effect was also smaller in the ageing group, which the authors explain by the still lower performance by the older participants. It is also possible that the differences in brain activity were caused by one of the several methodological distinctions between this and the previous study, which weakens the authors' conclusion.

Apart from the three old/new effects described, some ageing studies have found another effect, in which remembered items are more negative-going than correct rejections. This effect has a fronto-central distribution, is maximal on left scalp sites, and occurs between 500 and 1200ms after item onset for older adults but not for younger adults (Friedman et al., 2010; J. Li, Morcom, & Rugg, 2004; Swick, Senkfor, & Van Petten, 2006). Similar left-frontal negativity was found by Duarte et al. (2006). They compared younger adults with high- and low-performing older adults in a remember/know test for images. The younger and high-performing older participants showed similar left-parietal effects, though these had a later onset and offset in the older group. However, the low-performing older group not only did not show this typical old/new effect, but also showed a frontally distributed negativity. Kamp and Zimmer (2015) found better memory performance for younger adults in a remember/know test, and a negative-going old/new effect in older adults only (though no direct comparisons were made between the age groups), but this was parietal in distribution. The presence of this negative-going activity suggests that ageing leads to the use of compensatory retrieval strategies (Friedman et al., 2010), mainly when retrieving source information (Swick et al., 2006). It may also suggest that younger and older adults use equally efficient but qualitatively different retrieval strategies. Accordingly, younger adults could be focusing on the abstract or conceptual details from the event and older adults could be retrieving the more physical of perceptual information (J. Li et al., 2004), which is less cognitively demanding (Friedman, 2013). This activity may also signal the allocation of attentional resources that help older adults to engage in the task in hand and enhance retrieval (Friedman et al., 2010).

In summary, the ERP literature reviewed above suggests that the effects of ageing on memory are more complex than they seem when only behavioural findings are analysed. Although performance data almost consistently suggest that older adults are less accurate in recollection than familiarity (as reviewed in the previous section), the old/new effects are not so clear cut. It seems likely that the mixed findings may be caused by individual differences in the ageing population, such as performance and educational levels (e.g. Angel et al., 2010; Duarte et al., 2006), or by methodological differences. For example, Ally et al. (2008) tested retrieval-related activity for pairs of images and of words, and found the mid-frontal and left-parietal effects to be similar in the two age groups when the stimuli were pictures. In contrast, words elicited reduced effects in the older group, which corresponded to their lower performance with those stimuli compared to images. These findings suggest that older adults may find it easier to memorise certain types of events over others. One important manipulation that substantially affects older adults' memory is the emotional valence of the to-be-remembered event. This will be reviewed next.

Episodic memory, ageing and emotion

Emotions can be defined as psychophysiological responses of value attribution to a stimulus (Dolan, 2002), or as subjective experiences accompanied by organic and behavioural displays (Damasio, 2000). Emotions have a strong modulatory effect on mnemonic processing, affecting one's future behaviour (Dolan, 2002). That happens because emotional events are usually the most relevant ones, and remembering them will shape one's decisions and behaviour in a more optimal way (Dolan, 2002). The brain structure most frequently associated with emotions is the amygdala, whose activity during encoding and retrieval correlates with memory performance for negative and positive stimuli (Cahill et al., 1996; Dolcos, LaBar, & Cabeza, 2005; Hamann, Ely, Grafton, & Kilts, 1999). However, other brain regions have also been linked to the processing of emotional stimuli via their connections to the amygdala, such as the hippocampus, the parahippocampal gyrus and the prefrontal cortex (Murty, Ritchey, Adcock, & Labar, 2010; Phelps, 2004). Previous research supports the idea that the amygdala and the medial prefrontal cortex are preserved in ageing (Chow & Cummings, 2000; Dolcos, Iordan, & Dolcos, 2011), leading to maintenance or even improvement of emotional processing in older adults.

A vast number of studies have found that emotion benefits memory performance (Buchanan, 2007; Hamann, 2001). Nevertheless, the reasons behind this improvement may be more complex than it might appear. Bennion, Ford, Murray, and Kensinger (2013) reviewed a series of studies about emotional memory and found that the beneficial effect of emotion on memory may be caused by two confounding factors. The first is that emotional stimuli are usually more semantically connected than neutral ones, which can increase the feeling of familiarity for emotional stimuli, increasing their recognition. This idea is supported by findings showing participants to be more liberal when responding to emotional items, since response bias for such items is larger (Dougal & Rotello, 2007). This pattern has been found in younger and in older adults (Kapucu, Rotello, Ready, & Seidl, 2008). The second factor that may confound emotional memory studies is the usual higher distinctiveness of emotional items than neutral ones. Thus, the better memory seen for emotional items may be caused by their novelty rather than their valence (Bennion et al., 2013).

Another important distinction that must be made is related to which component of an event is the emotional one. If the emotional component is the main one, there is usually a trade-off, where memory for that component is enhanced whereas memory for the peripheral components is reduced (Easterbrook, 1959). This is thought to happen because the emotional central item attracts most of the attentional resources during encoding, removing attention from the remainder of the event (Easterbrook, 1959). In two studies, Kensinger, Piguet, Krendl, and Corkin (2005) presented younger and older participants with images that contained one neutral or negative central item together with a neutral peripheral item. In the first study, the pairs of images were incidentally encoded, whereas in the second one, the encoding was intentional. Results showed the expected trade-off for the incidental study in both age groups. That is, when the central item was negative, memory for this item was enhanced whereas memory for the peripheral neutral item was decreased. This effect has been replicated in other investigations (Kensinger, Gutchess, & Schacter, 2007; Waring & Kensinger, 2009). However, when participants were instructed to memorize all elements of the image, younger adults were able to overcome the trade-off, whereas older adults still showed decreased memory for items on the periphery of negative central stimuli, compared to items on the periphery of neutral stimuli. This is probably due to older adults having difficulties in using encoding strategies that associate the different pieces of information in an event (Naveh-Benjamin, 2000). These difficulties may be overcome when older participants are given appropriate strategies and are instructed how to use them (Glisky, Rubin, & Davidson, 2001). The findings are different when the contextual information is the emotional one. For example, a series of experiments measured younger and older adults' memory for perceptual and for emotional context (May, Rahhal, Berry, & Leighton, 2005; Rahhal, May, & Hasher, 2002). In those studies, participants encoded images connected with either perceptual or emotional information (e.g. colour or safety). A source memory task revealed that older adults were worse in retrieving the perceptual context, but performed equally well when retrieving the emotional context of the image. This supports the idea that the usual memory deficits seen in older adults may be eliminated if an emotional element is present, since emotional processing seems to be preserved in ageing (Dolcos et al., 2011).

Importantly, the idea that emotional processing is preserved in ageing becomes more complex when looking at negative and positive valence separately. An extremely widespread idea in the literature, which will be explained next, says that ageing brings about a shift in which type of emotion is attended to and remembered. On the one hand, the Negativity Bias hypothesis states that younger adults focus their attention primarily on negative events and therefore remember those better than positive ones. This bias may occur because events of negative valence are especially influential during adaptation in this age group, i.e. for survival and reproduction (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Galli et al., 2011; Rozin & Royzman, 2001). On the other hand, the Positivity Effect hypothesis states that older adults show the opposite pattern, remembering positive events better than negative events. This would happen because older individuals are aware that they will not live much longer, thus displaying fewer negative emotions and relying more on positive events from the past (Carstensen & DeLiema, 2017; Carstensen & Mikels, 2005; Mikels, Larkin, Reuter-Lorenz, & Carstensen, 2005; Petrican, Moscovitch, & Schimmack, 2008). The Positivity Effect hypothesis is derived from the Socioemotional Selectivity Theory (Carstensen, Isaacowitz, & Charles, 1999). This theory states that the goals of a person are formulated according to his or her temporal context, which is the way the remaining life time is perceived. While young people think of their future as a long time and are motivated by the pursuit of knowledge, older individuals are aware that there is not much time left. They instead put their cognitive resources into the search for emotionally meaningful experiences.

A recent meta-analysis showed the Negativity Bias and the Positivity Effect to be reliable in long-term and working memory (Reed, Chan, & Mikels, 2014). However, many studies have not observed a bias towards positive information in older adults (Belham et al., 2013; Belham et al., 2017; Denburg, Buchanan, Tranel, & Adolphs, 2003; Fernandes, Ross, Wiegand, & Schryer, 2008; Fung et al., 2008; Gruhn, Smith, & Baltes, 2005; Newsome, Dulas, & Duarte, 2012; Satler & Tomaz, 2011). The discrepancies between studies have been explained by cultural and methodological differences. For instance, Denburg et al. (2003) tested younger and older adults in three different tasks that measure different components of memory. The free-recall task required participants to write down as many items as could be retrieved and was considered to assess recall memory for gist. The cued recall task measured memory for both gist and visual details by asking participants a series of multiple-choice questions about the encoded images. Lastly, the four-choice recognition task required participants to indicate the correct old image amidst three highly-similar lures, measuring memory for visual details. Results showed no interaction between age and valence when using free recall, cued recall or forced-choice tasks with two different delays. However, younger and older adults showed better accuracy for negative images in the free recall task, no difference in the cued recall task, and better memory for neutral items in the forced-choice task. This suggests that the positivity effect is not a universal phenomenon and depends on what part of the information is being retrieved (Denburg et al., 2003). That study can be criticised for conducting the different tasks in the same order for all participants, which could potentially lead to one influencing the other. Nevertheless, these findings indicate that there is still a long way before the interactions between emotion and memory in ageing are unveiled and that more studies on this topic are fundamental.

Recently (Carstensen & DeLiema, 2017), the research group that originally proposed the Positivity Effect argued that differences in encoding tasks were the reason why some studies had failed to find better memory for positive items in older adults. The authors claim that, in their studies, participants passively view stimuli, whereas in other studies, participants are required to make decisions or judgments during encoding. These decisions would artificially change the natural goals of older adults, reducing or eliminating the Positivity Effect. However, two of the studies previously mentioned in this thesis asked participants to look at the stimuli "as though they were watching television" and still did not find a Positivity Effect (Fernandes et al., 2008; Fung et al., 2008). So, although Denburg et al. (2003) and Carstensen and DeLiema (2017) propose explanations for the mixed findings in relation to emotional memory in ageing, the circumstances in which the Positivity Effect and the Negativity Bias are found are still not clear.

It is important to note that the Socioemotional Selective Theory is not the only explanation for the Positivity Effect in the literature. Another interpretation has been raised, although it does not necessarily compete with the Socioemotional Selective Theory. Kensinger and Leclerc (2009) claim that changes in how older adults process different valences are functional and not structural. They base this on findings showing that brain areas related to emotional processing are preserved in ageing (Chow & Cummings, 2000; Dolcos et al., 2011) and propose that functional changes result from an enhanced self-reference effect (Rogers, Kulper, & Kirker, 1977). The self-reference effect corresponds to the mnemonic advantage that items processed in relation to oneself have in comparison to other types of information, caused by deeper and/or associative encoding (Klein, 2012). Studies have shown that older adults benefit from the self-reference effect to the same extent as younger adults when positive and negative information are combined (Mueller, Wonderlich, & Dugan, 1986). However, older adults seem to show more self-referential processing with positive items than do younger adults (Gutchess, Kensinger, & Schacter, 2007; Leclerc & Kensinger, 2008). Thus, Kensinger and Leclerc (2009) suggest that by utilising more self-referential processing with positive items, older adults consequently enhance their memory for such items. Although interesting, this theory needs more evidential support. This is because Gutchess, Kensinger, et al. (2007) found age-related differences in brain activation but not in memory performance, and Leclerc and Kensinger (2008) measured the engagement of brain areas connected to self-referential processing but did not test participants` memory. In summary, at least two proposals exist to explain the enhanced memory performance of older adults with positive items. More importantly, the Positivity Effect is, in its own right, debatable, since many studies have failed to find it. In the next section, ERP findings are reviewed in order to dig deeper into the underlying mechanisms of the interactions between ageing and emotion in memory.

ERP findings on the interaction between memory, ageing and emotion

The mnemonic advantage of emotional stimuli seems to be reflected in ERP data. For example, Dolcos and Cabeza (2002) found that the activity for images later remembered in a free recall test was more positive-going than the activity elicited by later forgotten trials and that this Dm effect was larger for emotional images at central electrode sites between 400-600ms after image onset. This type of activity resembles the one seen in the early Dm studies and later replicated with faces and deeply encoded information (Guo, Voss, et al., 2004; Guo, Zhu, et al., 2004; Paller et al., 1987). The larger Dm effect with emotional stimuli is used to explain participants' better performance with those items, since it may represent earlier access to encoding-related neural mechanisms, increasing later memory (Dolcos & Cabeza, 2002; Yick, Buratto, & Schaefer, 2015). More recently Yick et al. (2015) used neutral and negative images in an intentional encoding task and found that the latter elicited a larger Dm effect composed of widely distributed positive-going activity from 400ms after image onset. Although this larger positivity for emotional items during encoding seems to be consistent in younger adults, it is unclear how ageing affects Dm effects. fMRI studies suggest that the emotional valence of stimuli influences which brain regions are more activated in different age groups. Addis, Leclerc, Muscatell, and Kensinger (2010) analysed Dm effects of younger and older participants when they memorized negative, positive and neutral images. The results revealed that, for negative items, the age groups showed similar patterns of connectivity between prefrontal regions, the amygdala, and hippocampus. Interestingly, for positive items, only older adults showed strong connections between the hippocampus, amygdala and prefrontal cortex. This suggests that the Positivity Effect, if real, is caused by a beneficial effect of positive emotions in older adults, rather than a detrimental effect of negative events (Addis et al., 2010). This suggests that older adults particularly benefited from positive emotions during encoding, in accordance with the Positivity Effect hypothesis, and also opens up the possibility that ERP results during encoding will be influenced by age.

With regards to retrieval activity, Newsome et al. (2012) tested younger and older participants in a recognition memory task for positive, negative and neutral images and found that a very early effect on left-posterior sites, between 150 and 250ms, was present only for negative images in younger adults, and only for positive items in older participants. The other old/new effects were not affected by ageing. This suggests that different valences may have priority access to cognitive resources in younger and older adults also during retrieval. Another investigation about retrieval-related brain activity for emotional items in ageing was done by Langeslag and Van Strien (2008). These authors used a continuous recognition memory task and found an overall decline in memory performance for older adults. Interestingly, in younger adults, only the left-parietal effect was larger for the emotional items, whereas for older adults, only the mid-frontal effect was larger for emotional items. These findings suggest that younger and older adults use different retrieval mechanisms (recollection and familiarity, respectively), and that these effects are both modulated by the emotional valence of the item.

Eppinger, Herbert, and Kray (2010) investigated how positive and negative learning affects memory in younger and older adults. The authors manipulated the (financial) feedback received by younger and older participants after an answer in an encoding task. Both age groups showed better memory performance for images learned in the positive feedback context. Results showed a regular left-parietal effect for younger adults and none for older adults, who also performed worse. Interestingly, the mid-frontal old/new effect did not differ between the age groups but was only present for positive feedback. The authors suggest that positive feedback led to the unitization of the image with the positive valence, making it easier to be retrieved by familiarity mechanisms. This type of manipulation does not seem to affect recollection mechanisms. It is worth highlighting that although reward and emotion may not be synonymous, they are thought to elicit similar motivational processes and brain structures (Aron et al., 2005; Blood & Zatorre, 2001; Lang, Bradley, & Cuthbert, 1998), making the study of reward relevant to the study of emotions. Although Newsome et al. (2012), Langeslag and Van Strien (2008) and Eppinger et al. (2010) used different tasks and slightly different time windows, they all found that when older participants showed a smaller left-parietal effect, they also performed worse, suggesting that this is a reliable neural correlate of recollection. The influence of emotions on the old/new effects may not be straightforward, but the reviewed literature shows that the interaction between ageing and emotion is present during encoding and during retrieval.

The brain activity in preparation for the encoding of a stimulus has also been shown to be influenced by emotion, although interactions with ageing are unknown. Galli et al. (2011) presented young participants with neutral, negative and positive images preceded by schematic facial cues that indicated the upcoming valence. Dm effects after image onset were positive-going and anteriorly-distributed but did not differentiate between valences. Crucially, however, prestimulus Dm effects were strongly influenced by valence, being significant only before negative images in female participants. The authors explained this finding by the evolutionary and biological importance of negative events, which usually bear the most relevance to one’s survival. This idea is supported by findings of the face-in-the-crowd paradigm, showing that negative stimuli are more quickly identified and localised (e.g. Pinkham, Griffin, Baron, Sasson, & Gur, 2010). Therefore, prestimulus activity seems to allow a more prompt and efficient response to negative events. The result is thought to have occurred only in females because they are more emotionally responsive (Galli et al., 2011). The lack of behavioural differences despite differences in brain activity may be explained by a possible compensation during retrieval, i.e. prestimulus activity is one stage of mnemonic processing, but not the only one to define performance (Galli, Griffiths, et al., 2012). That is a valuable reason as to why to look at multiple time points during the study of memory.

In another study, Galli, Griffiths, et al. (2012) used the above-mentioned approach, but added a new condition. This time, in half of the trials, participants would simply view the negative images (control condition), and in the other half, they had to down-regulate their emotional response. Like the first study, all images were preceded by cues indicating the upcoming valence and participants should make an indoor/outdoor judgment for each. Similar to the original study, the findings showed that significant Dm effects were only present before negative images in the control condition, though the effect in the first study showed a wider topographical distribution. Importantly, no valence in the emotion regulation condition showed prestimulus Dm effects. This suggests that the anticipatory role of prestimulus activity can be modulated by emotion regulation and that participants begin the regulatory processes even before seeing the target stimuli. This is relevant because it supports the idea that prestimulus activity is influenced by the way one engages with the emotional content of an event. Seeing that older adults deploy different brain areas and connectivity than younger adults for different valences (e.g. Addis et al., 2010), it is plausible that ageing influences prestimulus activity.

Also regarding prestimulus activity for emotional items is the study by Padovani, Koenig, Brandeis, and Perrig (2011). These authors presented participants with words that should be judged according to their emotional or semantic content. The words were preceded by cues that indicated the type of decision that should be made. Prestimulus activity for semantic judgments showed a negative-going frontal Dm effect, similar to the one found previously and related to semantic processing (Otten et al., 2006, 2010). However, activity preceding emotional judgments was composed of a centrally-distributed positivity that resembled the one described above (Galli et al., 2011, 2012). These findings indicate that participants were using the cues to get into the right “task set” and that emotion generates specific prestimulus Dm effects.

These studies clearly show that emotion and memory interact even before stimulus onset. Although none of them involved older participants, it is possible to hypothesise how the emotional prestimulus effects would manifest in ageing. For example, considering the Socioemotional Selective Theory explained earlier, it is reasonable to assume that Galli et al. (2011)’s prestimulus Dm effect for negative images would happen for positive images in older adults, since this age group focus on and attends to positive events more than to other valences. Such finding would support the Positivity Effect hypothesis and help to explain older adults’ preference for positive stimuli.

Additionally, Galli, Griffiths, et al. (2012)'s results on emotion regulation could potentially also differ in older adults. That is because ageing is related to an improved ability to utilize some emotion regulation strategies (Shiota & Levenson, 2009), i.e. the process by which one can change, controlled or automatically, which emotions are felt as well as when and how they are felt (Gross, 1998). Urry and Gross (2010) propose that older adults are better at avoiding negative stimuli, focusing on the positive ones, and also re-evaluating an event to give it a positive connotation. Thus, studies about encoding-related prestimulus Dm effects in older adults can be key to explain emotional shifts that have been documented in cognitive ageing.

The idea that older adults are superior at emotion regulation leads to the question of whether they are also better at emotion attribution. That is, if ageing improves one's skills to reduce the valence of an item or even to shift it into a different valence, does it also enhance their abilities to add emotionality to events? This is a fundamental question, since it involves the development of preferences and attitudes towards objects and other people (De Houwer, 2007). Kensinger and Leclerc (2009)`s proposal that older adults engage in self-referential processing to a higher degree than younger adults would support age-related differences in the attribution of emotions to information. Additionally, the mnemonic advantage of emotional episodes over neutral ones is fairly well established (see discussion above). However, the possibility that neutral items that have acquired emotionality are also better remembered remains to be investigated. In this thesis, emotion attribution was manipulated and quantified according to the evaluative conditioning literature, which will be reviewed next.

Evaluative Conditioning

Definition and characteristics

Evaluative conditioning (EC) can be defined as the change of valence of a neutral stimulus due to its pairing with an emotional stimulus (Jones, Olson, & Fazio, 2010; Levey & Martin, 1975; Martin & Levey, 1978). EC is thought to influence many everyday decisions, from the brands bought in the supermarket to the politician voted for, as well as attitude towards objects, people and oneself (De Houwer, 2007; Dijksterhuis, 2004). In short, the joint presentation of a stimulus A with an emotional stimulus B will cause A to acquire the same emotional status as B. In other words, people's attitudes towards B are transferred to A (Levey & Martin, 1975).The first empirical demonstration of this effect was done by Levey and Martin (1975). These authors started from the then current idea that the conditioning of muscle and gland responses in non-human animals should not be so different from the more complex and elaborate affective responses seen in humans. Thus, they created a procedure to assess the conditioning of affective evaluation. The study of this topic is important because emotional evaluation is adaptive, stable and individual, allowing for the plasticity of our behaviour (Levey & Martin, 1975). Emotional evaluation also has a strong impact on the regulation of subjective experience and behaviour in many life situations (Levey & Martin, 1975). In fact, in areas like food preferences, for example, learning and conditioning can have greater influence than genetics (Rozin & Millman, 1987). Levey and Martin's experiment (1975) consisted of presenting participants with pairs of postcards. The pairs were always composed of one neutral card and one emotional card, either negative or positive. The distinction between the valences was made by each participant at the beginning of the session. Two neutral-positive, two neutral-negative and one neutral-neutral pairs were presented 20 times each. After that, participants rated all the neutral images according to how much they liked or disliked each of them. What the authors found was a higher rating for neutral cards paired with positive cards when compared to neutral cards paired with negative cards. The cards paired with neutral cards were rated as positive, but to a lesser degree than the ones paired with positive cards. The authors classified this finding as an "intriguing puzzle" and did not provide an explanation. The methodology of choosing the positive and negative stimuli based on each participant's initial rating has since been replaced by using emotional stimuli taken from a validated database, such as the International Affective Picture System, IAPS (Lang, Bradley, & Cuthbert, 1997), as can be observed from the more recent literature reviewed later in this section.

Levey and Martin (1975) adopted the same terminology used in classic conditioning experiments to describe the emotional stimulus as the Unconditioned Stimulus (US), the neutral stimulus as the Conditioned Stimulus (CS) and the affective evaluation of stimuli as the conditioned response. Baeyens, Eelen, Crombez, and Van den Bergh (1992) argue that EC is not a sub-type of classic conditioning, but an independent process. Their reasons are that, in humans, classic conditioning is sensitive to extinction and involves the participants' awareness of the CS-US contingencies. On the other hand, EC is thought to be resistant to extinction and independent of awareness. Walther, Weil, and Dusing (2011) agree with these distinctions by claiming that the EC effect remains present even after repeated presentations of the CS without the US. More recently, neuroimaging studies supported the distinction between classic conditioning and EC. Coppens et al. (2006) showed that EC is intact in patients with unilateral lesions in the amygdaloid nuclear complex, which had been shown to be crucial in classic conditioning studies. However, the arguments by Baeyens et al. (1992) and Walther et al. (2011) have been called into question. For example, a meta-analysis concluded that EC's resistance to extinction is not statistically sound (De Houwer, 2007). More importantly, there is a long-lasting dispute in the literature about whether EC depends on contingency awareness, which will be defined and discussed in the following section in this thesis.

In the more than 40 years since the first published papers on EC, a lot has been done. Researchers have tested different modalities of stimuli, experimental designs, procedures and analyses in order to gain a better understanding of the mechanisms behind EC, its consequences for human behaviour, and in which conditions the effect is present. For example, Bayliss, Frischen, Fenske, and Tipper (2007) investigated whether evaluative conditioning occurs by simply observing other people's preferences. The authors paired neutral objects with emotional faces that were looking at the objects or away from them. EC was only present for the trials when the faces gazed at the objects, suggesting that our attitudes and preferences may be acquired because of other people's likings. Another example is the study by Gast and Kattner (2016), who aimed to assess the influence of memory on EC effects by applying the conditioning procedures when participants were instructed to remember the pairings and when they were directed to forget them. EC was significantly larger when memorization was instructed, suggesting that memory and EC are strongly linked. Moreover, Fulcher, Mathews, Mackintosh, and Law (2001) tested how individual differences affect EC. Their participants performed a probe detection task with neutral words that had been paired with negative images. Results showed that participants with high scores on neuroticism were more strongly affected by the now negative words. This indicates that some people have an intrinsic tendency to transfer the negative valence of one stimulus to another. Due to these and many other studies it is now known that EC is a real and solid effect, though the circumstances in which it occurs are not yet completely clear (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010).

Theories underlying evaluative conditioning

One constantly debated issue in the EC field involves the role of contingency awareness in the conditioning effect, since this is at the core of the different theoretical accounts to explain EC. Contingency awareness happens when participants have explicit knowledge about the types of pairing being presented during the conditioning stage (Walther & Langer, 2008), for instance, when participants notice and realize that one particular colour is always paired with a positive image. Contingency awareness must not be confused with demand awareness, which happens when participants are able to guess the experimenter's hypothesis and perform according to the expectations. These are independent characteristics. For example, one participant may guess that their evaluative ratings are expected to change, without noticing the specific contingencies of the task, whereas another participant may notice the pattern behind the pairs, but not realize that they are supposed to change future evaluation (De Houwer, Thomas, & Baeyens, 2001).

There are currently two main accounts to explain EC and each make different predictions regarding awareness. The Misattribution Account, described by Jones, Fazio, and Olson (2009), explains that the emotional response elicited by the US is confounded as having been elicited by the CS, i.e. there is an implicit misattribution of one to the other. This explanation predicts that EC will only happen in the absence of contingency awareness. This is because if people realize the pattern of the pairings, there will be less confusion between which stimuli elicited their response and, as a consequence, there would be no misattribution. On the other hand, the Propositional Account, defended by Mitchell, De Houwer, and Lovibond (2009), says that EC happens due to propositional knowledge about the relationship between CS and US. In other words, it is not sufficient that US and CS share a linked mental representation. It is necessary that one is explicitly aware of the specific nature of the relationship between the two stimuli. One way to explain the difference between having a mental link and being aware of the specific relationship are sentences that have the same elements in different orders. For example “The monkey ate the banana” and “The banana ate the monkey” have the same words but different meanings due to the distinct structural organization of those words (Shanks, 2007). The Propositional Account argues that EC only happens when the structural organization and the relationship between elements is explicitly known. Thus, this account predicts that EC only happens when contingency awareness is present, since people need to learn about the pairings via a conscious and effortful mental process. In summary, elucidating whether EC is dependent or independent from contingency awareness may help resolve the debate between these two accounts (Walther et al., 2011). If contingency awareness is necessary for EC, the Propositional Account will gain support. If, however, contingency awareness is found not to be fundamental for EC, the Misattribution Account will be supported.

Some authors have suggested that EC may have different forms, one dependent on contingency awareness, and one not (De Houwer, 2007; Walther et al., 2011). This possibility is the core of the Associative-Prepositional Model, created by Gawronski and Bodenhausen (2011). This model tries to link the Misattribution and Prepositional Accounts by suggesting that conditioning is a multiple – instead of single – learning process, each with its own mechanisms (Lovibond & Shanks, 2002). In this model, the authors suggest that implicit and explicit changes of evaluation are caused by mental processes that are qualitatively different. The spatial and temporal contingencies of US and CS would create mental associations that are retrieved next time the CS is seen, resulting in "gut reactions" or implicit conditioning. If these activated associations are consistent with the person's beliefs about themselves and the words, explicit reactions will also be present. However, if the "gut reaction" is inconsistent, only implicit, but not explicit, EC will be present. An analogy to this model can be found in the literature about stereotypes and prejudice (Devine, 1989). Stereotypes may be viewed as automatic reactions to culturally and socially present associations between a group and a characteristic. Prejudice is the controlled and conscious reaction to those associations based on one's beliefs. Although two people raised in the same society will automatically learn stereotypes and may show quick responses to certain groups, a low-prejudice person will decide that that stereotype is inappropriate and not act upon it any longer. In contrast, a high-prejudice person will accept the stereotype and extend their now conscious responses accordingly. With the Associative-Prepositional Model, the authors help to explain results in the literature where explicit ratings and implicit ratings show different patterns (e.g. Gawronski & Walther, 2012; Hu, Gawronski, & Balas, 2017b). Additionally, the understanding of the relationship between EC and awareness could have a broader influence in cognitive theories that propose the existence of an implicit and/or explicit route of learning (Hutter, Sweldens, Stahl, Unkelbach, & Klauer, 2012; Sun, Slusarz, & Terry, 2005).

A recent study found interesting results supporting the Associative-Prepositional Model. Hu, Gawronski, and Balas (2017a) manipulated the relational information between the emotional and neutral stimuli, i.e. they presented participants with conditioning trials that had the same elements but in different structures. More specifically, the pair involved neutral fictional pharmaceutical products and negative or positive health conditions. In half the trials, the pairs were accompanied by a sentence saying that the product caused the condition ("cause condition"), and in the other half, the sentence said the product prevented the condition ("prevent condition"). EC effects were measured in two tasks. The first one required participants to indicate how much they liked or disliked each brand from the study phase. The second one was a priming task, in which participants should indicate whether a word was negative or positive following a very quick presentation of the words from study phase. According to the authors, the first task works as an explicit measure of EC, whereas the second one is an implicit measure. Results showed that explicit EC effects were only present for the "cause condition". The "prevent condition" showed a near-significant reversed EC effect. However, implicit EC effects were present but not modulated by the experimental conditions. These findings suggest that the mere mental link between emotional and neutral stimuli is enough to cause implicit EC effects. However, explicit effects are dependent on participants knowing the specific relationship between the two stimuli, as predicted by the Associative-Prepositional Model.

The investigation of the relationship between awareness and conditioning will also improve the understanding of real-life effects of EC. For instance Gawronski and Walther (2012) studied whether EC is a controllable effect. That is, if one knows that a particular commercial brand has purposely associated its slogan with a happy event, can one prevent themselves from liking this brand? Gawronski and Walther (2012) showed that emotion regulation techniques are able to lower EC strength in explicit ratings but not in implicit ratings. The authors concluded that even if one is aware of the strategies used during EC and try to control their emotional responses, the automatic learning and conditioning will still occur.

Despite the importance of understanding the connection between awareness and EC, some practicalities have been shown difficult to overcome. The main question is how contingency awareness should be measured. The most direct way would be to question participants during the pairing task; however this would likely direct their attention to the relationship between stimuli, increasing demand awareness and biasing the study (Lovibond & Shanks, 2002). The solution found by most authors is to add a memory task after the procedure and measure how well participants remember the associations. This is not the ideal answer to the problem either, because participants will be affected by delay and, more importantly, awareness after conditioning is not necessarily equal to awareness during conditioning (Gawronski & Walther, 2012; Lovibond & Shanks, 2002). That is, a poor (or good) memory performance does not guarantee there was low (or high) awareness during pairing. Memory performance in EC is used, therefore, as a proxy for contingency awareness (Stahl & Unkelbach, 2009).

Evaluative conditioning and episodic memory

By seeing memory as a way to tap into contingency awareness, the EC literature has commonly used suboptimal memory tasks. Firstly, most studies on EC use very few unique pairs of each valence (Field & Moore, 2005; Fulcher et al., 2001; Halbeisen, Blask, Weil, & Walther, 2014; Pleyers, Corneille, Luminet, & Yzerbyt, 2007). Bar-Anan, De Houwer, and Nosek (2010), for instance, use only one positive and one negative CS-US pair. These pairings are also usually presented repeatedly, which increases memory (Oberauer, Jones, & Lewandowsky, 2015). Therefore, many studies reach a ceiling effect on their memory tasks, making it difficult to describe the effects of low memory on EC (Hutter et al., 2012). One recent exception to this pattern is the study by

Gast and Kattner (2016), who used 40 positive pairs and 40 negative pairs and only one presentation of each. However, participants were tested for their memory and evaluative ratings after small blocks of 8 pairs each, making the memory task significantly easier. Another difference is that in typical EC studies there is an absence of new items during the memory task, which makes it impossible to investigate if participants can, in fact, discriminate between stimuli they have and have not seen before. To understand the relationship between memory and EC, it is necessary to investigate not only how the contingencies are remembered but also how the conditioned items are retrieved.

Secondly, another concern with the memory tasks used in the EC literature is the data analyses. For a long time, EC studies would use memory performance to separate participants into two groups (Pleyers et al., 2007). The low performance group would be considered unaware of the contingency during the conditioning task, and the high performance group would be classified as aware. This way, between-group analyses would be done in order to test whether awareness was necessary for EC. However, low and high performances are usually not made up of 100% incorrect or correct trials. Thus, participants considered unaware were still able to remember some items and participants considered aware had forgotten a few. Pleyers et al. (2007) noticed this inconsistency and proposed an item-based analysis, in which ratings are compared between remembered and forgotten items in a within-subject fashion. In their study, eight fake brands were paired with four positive and four negative images. Participants then rated the brands according to their liking and were asked to indicate with which valence each had been paired before. The authors conducted the usual participant-based analysis and the new item-based analysis on the data. In the first case, both groups of aware and unaware participants displayed EC effects, indicating that conditioning happened regardless of awareness. On the contrary, item-based calculations showed that EC was only present for remembered items, allowing the authors to conclude that the latter was a more accurate way of testing the relationship between EC and awareness. It is important to note that the commonly small number of used stimuli leads to the exclusion of some participants on the item-based analysis due to their very good performance, as explained above. Even Pleyers et al. (2007) admit that the small number of items and very good memory performance decrease the statistical power of their study.

One interesting alternative for using memory tasks as a simple measurement for awareness is to study EC in patients with diagnosed memory problems. Some examples of patients who are typically amnesic but show preserved EC are people with Korsakoff's Syndrome (Johnson, Kim, & Risse, 1985), dementia (Blessing, Zollig, Weierstall, Dammann, & Martin, 2013), and lesions in the amygdala and the hippocampus (Somerville, Wig, Whalen, & Kelley, 2006; Todorov & Olson, 2008; Tranel & Damasio, 1993). These studies showed preserved EC effects in those populations, suggesting that EC is an automatic process, independent of explicit memory.

A few attempts to test the effects of memory manipulations on EC have recently been done by Anne Gast and colleagues. Gast, De Houwer, and De Schryver (2012) paired Chinese characters with negative, positive and neutral IAPS images and tested (non-Chinese speaking) participants in a likeability and memory tasks for the pairs, immediately after conditioning or nine to ten days later. The results showed that EC effects in the second session were only present for items that were still remembered in that session. In contrast, items remembered in the first session but later forgotten did not show EC effects in the second session. Because of the low number of trials in each condition, the authors do not provide information on EC effects during the first session, so it is unclear whether the ratings changed with time. In another study, Gast and Kattner (2016) paired neutral pseudo-words with negative and positive words. In half the trials, participants were instructed to keep the pairs in mind, and, for the other half, they were told to forget the pairs since they would no longer be used in the study. Memory and liking were evaluated for each pseudo-word. Results showed that EC effects were larger for the pairs instructed to be remembered than for the ones instructed to be forgotten. However, as mentioned before in this chapter, the memory and the likeability tasks in that study were conducted after small blocks of eight pairings, which probably inflates memory performance. In a third study, Richter and Gast (2017) paired Chinese characters with negative and positive images and manipulated the spacing conditions during encoding. That is, some pairs were presented twice for four seconds with an eight-second interval between them, and some were also presented for four seconds but with a 100-second interval between them. In the control condition, the pairs were presented only once for a total of eight seconds. Likeability and recognition memory tasks were applied after the encoding phase. As expected from the literature (Sisti, Glass, & Shors, 2007), spacing increased memory performance. Similarly, EC effects were enhanced in the pairs presented in the spaced conditions. No differences were found between the eight and the 100-second leg conditions. The results also suggested that the effects of spacing on EC were caused by the effects of spacing on memory. However, it is known that repetition increases memory performance and may increase EC (Hofmann et al., 2010). Because there was no difference in the results between the eight-second and the 100-second leg conditions, it is unclear whether the findings are due to spacing or to repetition.

In addition to the studies by Gast and colleagues, Molet et al. (2016) investigated "affective learning" after manipulating memory performance (they do not mention the term EC or the literature behind it). These authors paired neutral faces with sentences describing negative or positive behaviours. In a previous task, participants provided likeability ratings for the faces. In a later task, participants saw the faces again and were instructed to either think about the behaviour, or not think about it using one of four techniques: participants were (a) simply told not to think of the behaviour without further instructions, (b) given emphatic instructions to keep the thought of the behaviours out of their minds, (c) asked to count backwards in order to distract themselves from thinking of the behaviour, and (d) given a substitute behaviour to think about. After the task, a recall and likeability task were conducted. Compared to the trials in which participants were instructed to think about the behaviour, the four "do not think" instructions elicited a significantly smaller change in likeability for the faces paired with positive behaviours. However, only instructions (b) and (d) lowered the change in likeability for the faces paired with negative sentences. Interestingly, the effects of memory were remarkably similar. The four instructions reduced memory for the positive trials, whereas only instructions (b) and (d) reduced memory for negative trials. The authors conclude that different thought suppression techniques can reduce emotional memories. Unfortunately, the authors do not mention the EC literature and do not discuss the findings in this light. Thus it is unclear if those results can be interpreted as a link between memory and EC. In conclusion, the studies described in this and the preceding paragraph, although not free from criticism, hint at a direct connection between memory and EC that clearly needs to be further investigated.

To sum up, the EC literature commonly uses memory as a proxy for measuring contingency awareness without minding procedural details that the memory literature finds important, such as the ceiling effect, the number of stimuli and the type of analysis. On the other hand, memory studies that investigate effects of emotion are typically not concerned with the fact that neutral stimuli might have their valence changed during the task. The possibility of EC was tentatively raised by Smith, Dolan, and Rugg (2004) in their study investigating ERPs during retrieval of neutral items that had been presented with emotional or neutral backgrounds. The authors found larger positive activity on right temporal scalp areas for CS paired with emotional stimuli. This activity was present more than 100ms before the recollection-related left-parietal effect, which suggested that it was not related to memory for the backgrounds. Similar activity had been found for emotional IAPS images when compared to neutral images (Keil et al., 2002). Thus, Smith, Dolan, et al. (2004) suggested that the neutral items had temporarily acquired some of the emotional features of the backgrounds. Although this may sound like EC, the authors provide no reference or citation for this explanation. An evaluative rating task in this study would argue for or against their suggestion. This case is an example of how the field of memory could be enriched by the study of EC. Another advantage of EC methods to look at memory is the use of only neutral items that were encoded in emotional context instead of testing emotional items themselves. This avoids the confounding factor of perceptual, distinctiveness, and arousal differences between the valences and stimuli (Bennion et al., 2013; Martinez-Galindo & Cansino, 2017).

The neural correlates of evaluative conditioning

Apart from Smith, Dolan, et al. (2004), other studies have investigated the memory brain correlates of neutral information encoded in emotional contexts without acknowledging the EC literature. For instance, in the study by Erk, Martin, and Walter (2005), neutral words were presented against emotional background images during encoding, followed by an item recognition task. There was no improvement of memory for neutral items encoded in emotional contexts. However, fMRI data showed activity of different brain areas when items encoded in different valences were retrieved. Although it may be that the neutral words acquired the emotional attributes from their original backgrounds, no reference to the EC literature was made in the paper.

In another study, Martinez-Galindo and Cansino (2015, 2017) measured ERPs Dm and old/new effects during encoding and retrieval of neutral faces paired with positive, neutral or negative (financial) outcomes. As mentioned before in this chapter, emotion and reward are thought to elicit similar motivational processes and brain structures (Aron et al., 2005; Blood & Zatorre, 2001; Lang et al., 1998), which makes the study of one relevant to the study of the other. In Martinez-Galindo and Cansino (2015, 2017), faces encoded in the positive condition were more accurately remembered. During encoding, faces paired with the positive outcome showed a larger positive-going activity at frontal sites than items paired with the other outcomes. During retrieval, only faces encoded in the positive condition elicited any old/new effects. These were the mid-frontal and the right-frontal effects. The authors also mention a modulation of the left-parietal effect in the discussion, but a more careful look at their results reveal that the effects in that particular time window were only significant on frontal electrodes. Because the faces that elicited differential Dm and old/new effects also elicited better memory performance, it is difficult to conclude whether these ERP effects were simply caused by better memory or by EC via the propositional mechanism explained earlier. Nevertheless, the results suggest that participants reacted differently to neutral information that is encoded with different emotional valences.

Jaeger and Rugg (2012) superimposed neutral objects on to neutral or negative background images and asked participants to imagine a connection between the two during encoding. Participants completed an old/new recognition memory task 24 hours after encoding. No differences between images encoded in neutral or in negative contexts were found when analysing performance and the mid-frontal and left-parietal old/new effects. However, an earlier positive-going old/new effect between 200-300ms was stronger at parietal sites for emotional trials. This is similar to the findings by Smith, Dolan, et al. (2004), who also showed that items encoded in different emotional contexts elicit different brain activity before the onset of the typical memory-related effects.

Previous research has also directly looked at the neural bases of EC. In one case, Davis, Johnstone, Mazzulla, Oler, and Whalen (2010) paired neutral faces with written negative, positive and neutral statements and measured amygdala activity. The faces were always presented before the sentences. Amygdala activity in response to the faces was compared between the first half of conditioning trials and the second half in order to evaluate if the acquisition of liking/disliking was connected with activity in that brain structure. Indeed, activity in the dorsal amygdala increased during the conditioning task for the negative and positive conditions but not for the neutral one. This finding suggests that the amygdala may play a role in connecting emotional value to originally neutral stimuli in order to predict threat or reward. This finding was shown in other studies (Iidaka et al., 2009), and found larger for people suffering from anxiety (Pejic, Hermann, Vaitl, & Stark, 2013).

Determining the neural processes behind EC may, for example, help with the awareness issue, supporting whether or not contingency is necessary (Lovibond & Shanks, 2002). In this line, Gibbons, Bachmann, and Stahl (2014) presented photos of neutral landscapes preceded by emotional words. They then compared ERPs between positive and negative trials. The authors also undertook a between-group analysis contrasting participants with strong versus weak conditioned responses. Results showed a larger sustained positivity on right-frontal sites elicited by landscapes that were preceded by negative words when compared with the ones preceded by positive words. Because this pattern had been seen in the processing of negative stimuli (Cunningham, Espinet, DeYoung, & Zelazo, 2005), the authors conclude that the landscapes acquired the valence of the emotional words via EC. Interestingly, the between-group analysis revealed that participants who showed the weakest EC effects displayed the largest attention-related ERP differences for the emotional words (before the landscapes). These findings support the Misattribution Account (Jones et al., 2009) explained earlier, since attention and deeper processing would allow participants to properly individualize the emotional responses elicited by the US and the CS, thus weakening EC.

Another major implication of understanding the neural basis of EC is the comprehension of how words acquire their emotional connotation. For example, Fritsch and Kuchinke (2013) investigated this question by pairing pseudo-words with negative and neutral images. Pseudo-words were used rather than real words to ensure they did not carry any previously learned emotionality. After the learning phase, participants completed a recognition memory task for the pairs and a rating task for the pseudo-words. Behavioural results showed that explicit and implicit ratings for pseudo-words paired with negative images were lower than for the ones paired with neutral images. Regarding the ERP data, pseudo-words paired with negative images elicited a larger P300 component, suggesting a successful coupling between the two. In a separate experiment (Kuchinke, Fritsch, & Muller, 2015), the authors added a positive condition to the test. Memory performance was larger for negative compared to positive trials, but neither differed significantly from neutral trials. The findings also showed that early ERPs during recognition of pseudo-words differed between the ones paired with negative emotions from the ones paired with positive emotions. This indicates that the pseudo-words acquired valence and that participants were able to identify these emotions in a rapid way (Stolarova, Keil, & Moratti, 2006). The ERP effects found in Kuchinke et al. (2015) were seen in an earlier time window than the ones found in Fritsch and Kuchinke (2013). The authors explain this difference by the fact that the pairs of pseudo-words and images in Fritsch and Kuchinke (2013) were presented simultaneously during the memory task and in Kuchinke et al. (2015) they were presented one after the other. So, according to the authors, in the more recent studies, activity in response to the pseudo-words may have clouded the presence of a possible P300 component for the images.

The neural basis of EC can also be used to understand how slowly-learned and socially meaningful responses arise (Wieser, Flaisch, & Pauli, 2014). Osinsky, Mussel, Ohrlein, and Hewig (2014) used the well-established Ultimatum Game, in which a virtual colleague (or avatar) offers fair or unfair sharing of their money to participants, who can accept or decline the offer. Objectively, participants should always accept the offer, no matter how unfair it may seem, in order to maximize their total reward. However, usually a negative reaction to unfairness makes people reject those types of offers and only accept the equal ones. Here, the authors propose that, if all the unfair proposals come from the same avatar, it will eventually become disliked, due to EC. Therefore, the authors expected that, after repeated exposure to an unfair avatar, the ERP feedback negativity (Miltner, Braun, & Coles, 1997) usually seen after bad offers would be elicited after the presentation of the avatar alone. This component is linked to a bad versus good evaluation and usually appears around 300ms at centro-frontal sites after an unfavourable event (Gehring & Willoughby, 2002). Results corroborated the hypothesis showing that the neutral avatar previously paired with the unfair proposals elicited the feedback negativity component even in the absence of the negative proposal. Thus, it was concluded that EC has an important role in generating social reputation and social preferences. Because the feedback negativity appears relatively quickly after stimulus onset (Gehring & Willoughby, 2002), it can be said that one`s attitudes towards others, once learned, are automatically activated next time those people are seen. This study offers an explanation for how people learn to identify the possible consequences of a future encounter with someone based on previous experiences shared with that person (Wieser et al., 2014).

In summary, EEG has been a useful tool to improve understanding of the mechanisms that underlie evaluative conditioning and real-life formation of attitudes and preferences. Older adults are a good candidate for future studies, since people in this age group interpret, regulate and memorise emotional information in different ways and also show distinct brain activities when processing such stimuli (Mather, 2012).

Evaluative conditioning and ageing

A search on the PubMed database with the words “evaluative conditioning” and “ageing” or “aging” returned zero results (11 September 2017). Two studies have, however, used older adults as controls for their EC studies. Blessing et al. (2013) investigated dementia patients and healthy controls by pairing four neutral faces with one positive or one negative face. Their results showed that older controls performed at chance level on the memory task and did not show EC effects. However, besides the fact that there was no younger group, the findings are admittedly clouded by small samples and outliers, making it difficult to draw a conclusion about EC in older adults. More specifically, out of the 14 older participants, 11 showed EC effects, but the remaining three showed a strong reverse effect, which could have influenced the fnal outcome. Todorov and Olson (2008) also used older adults as controls for patients with lesions in the hippocampus and the amygdale and presented neutral faces linked with emotional descriptions. They found that younger and older adults did not differ in the strength of EC effects.

Despite not using the term EC and not directly testing it, some studies have tapped into the formation of attitudes and preferences in the older population. For example, Olson et al. (2013) presented young and older adults with neutral faces associated with a short sentence describing whether the people depicted in the faces had been lucky or unlucky recently. After a delay, a forced-choice source memory task and an evaluative rating task were completed. Participants in both age groups liked faces connected to lucky statements more than the unlucky ones, but the effect was larger for older adults. Thus, from the very few studies that have used older adults in EC studies, one found no effects in this age group, another found similar effects in younger and older participants, and the third found larger effects in ageing. New studies aimed at the role of ageing in EC *per se* are, therefore, necessary to understand EC across the lifespan.

A better designed study of EC in older adults is important for practical, clinical, and theoretical points of view. In the practical sense, understanding how older adults respond to EC may aid marketing companies to create advertisements that speak to this population and stimulate them to consume. This topic was practically neglected until the 1980s with companies not including older adults in their surveys and not targeting them in marketing campaigns. Later, marketers realized that older adults are a heterogeneous group with a large purchasing power and started to invest in this population, but still find it difficult and challenging due to lack of research in the area (Moschis, 2003). One experimental study (Fung & Carstensen, 2003) has shown that older adults prefer and remember advertisements with emotional content more than the ones with knowledge content, whereas younger adults show no difference between the two types. More studies on how preferences are formed in the older population will contribute to marketing literature. From the clinical side, evidence that encoding information in positive contexts increases memory can potentially be used to develop new mnemonic strategies that help older adults with their usual problems of memory (Balota et al., 2000). The study of EC in ageing may help arbitrate between the different accounts that try to explain EC, mentioned above in this introduction. If older adults show preserved or larger EC despite overall lower memory, the Misattribution account would be supported, since it predicts that explicit memory for the associations is not necessary. However, if older adults show impaired EC, this could support the Propositional Account, which requires the presence of explicit memory for the associations.

From another theoretical point of view, it is already known that older adults deal with emotions in a different way than younger people, since they seem to have better memory for positive instead of negative events (Scheibe & Carstensen, 2010) and are more able to regulate their emotions (Urry & Gross, 2010). The concept of emotion regulation can be defined as one's attempts to influence his/her emotions by either manipulating its antecedents or components. Emotions' antecedents can be manipulated by controlling the chances of an emotional encounter, or by changing the way those emotional stimuli are appraised by masking natural physiological expressions, reinterpreting the event, or suppressing feelings (Gross & Munoz, 1995; Urry & Gross, 2010). When it comes to older adults, they seem to be more prone to naturally deploying emotion regulation strategies and are also more able than younger adults to regulate such emotions when instructed to do so (Urry & Gross, 2010). The idea of older adults being superior in emotion regulation started from the observation that, despite the bad effects of ageing on health and social relationships, older adults usually report higher levels of positive affect and lower levels of negative affect than younger adults. The more frequent and efficient use of emotion regulation strategies by older adults, particularly positive reappraisal (Shiota & Levenson, 2009), is connected to the Socioemotional Selective Theory explained earlier in this thesis. Thus, emotion regulation and EC can be seen as two sides of a coin: on one hand, emotion regulation can control and moderate feelings and, on the other hand, evaluative conditioning introduces feelings towards something otherwise neutral.

One study has directly assessed how emotion regulation affects evaluative conditioning. Gawronski, Mitchell, and Balas (2015) tested their EC procedure in younger participants that either simply observed the stimuli on the screen, or were instructed to use an emotion regulation technique. Results showed that emotion regulation reduced EC strength on explicit ratings. However, it also lowered memory for the pairings. Therefore, it is inconclusive whether emotion regulation directly affected EC or whether the results were mediated by the low memory performance. In other words, it is impossible to know the causal relationships between the factors in this study. Following the propositional account of EC (Mitchell et al., 2009), perhaps the use of emotion regulation removed the mnemonic advantage of the negative stimuli. In consequence, the lower memory for those pairings impeded EC. It is also possible that emotion regulation decreased the degree of emotionality involved in the pairings, directly leading to a weaker transfer of such emotions to the neutral stimuli. Importantly, in Gawronski et al. (2015) implicit ratings were not affected by the techniques used, which may suggest EC is not under cognitive control, or is composed of an automatic and a conscious process, as explained earlier in this thesis. These findings indicate that there is a lot left to be investigated about the links between conscious regulation of emotions and the conditioning effects. The study of EC in older adults will expand this knowledge by investigating how emotions are added to neutral information, which, in turn, may help explain the better memory for positive items in this population.

To sum up, although evidence supports age-related differences in the display, regulation and response to emotions, the effects of ageing on EC are virtually unknown. The study of this topic is, therefore, interesting and novel, having practical, clinical and theoretical importance as mentioned above.

Summary and research aims

At least two fairly consistent findings emerge from the literature reviewed in this chapter. Firstly, ageing brings deficits in episodic memory performance, mainly in recollection (Balota et al., 2000; Friedman, 2013). Secondly, neutral information can take up emotional valence after being paired with emotional stimuli (Hofmann et al., 2010). Although these two findings are not free from criticism (Bennion et al., 2013; Head et al., 2008; Pleyers et al., 2007), they have remarkably contributed to the understanding of the interactions between memory, emotion and ageing.

Nevertheless, some questions remain unanswered. Firstly, it is not clear which stage of the mnemonic processing sees the largest effects of ageing. Not only theoretical models disagree (Reuter-Lorenz & Park, 2010), but neuroimaging studies also show mixed results regarding encoding and retrieval (Friedman, 2003; Gutchess, Ieuji, et al., 2007). With the recent discovery that brain activity in preparation for stimulus encounters affects later memory (Otten et al., 2006), the relative contributions of encoding and retrieval to the deficits seen in ageing become even more complex. Therefore, the first aim of this thesis is to evaluate how different aspects of emotional memory are influenced by ageing. Chapter 3 looks at this question by investigating ERP effects during encoding – prestimulus and post-stimulus – and retrieval of emotional images in younger and older adults.

Secondly, despite the vast literature on memory for emotional episodes in younger and older adults, little is known about neutral items that have acquired emotionality. Compared to younger adults, older adults seem to attend to and remember positive stimuli more than the other valences (Carstensen & Mikels, 2005), engage in self-referential processing to a higher degree (Kensinger & Leclerc, 2009), and be more successful in emotion regulation strategies that enhance positive feelings (Urry & Gross, 2010). Thus, it is reasonable to investigate age-related differences in emotion attribution to neutral events. In this thesis, emotion attribution is investigated via the use of evaluative conditioning: the transfer of emotionality from one stimulus to another (Levey & Martin, 1975; Martin & Levey, 1978). Chapter 4 contrasts voluntary with instructed emotion attribution by people with different personality traits to test its effects on memory, a relevant issue empirically (Fulcher et al., 2001) and clinically (Ehring, Tuschen-Caffier, Schnulle, Fischer, & Gross, 2010). Chapter 5 looks at whether evaluative conditioning is present in older adults and its neural correlates. That chapter also manipulates memory performance to study the relationship between memory and evaluative conditioning, a much disputed topic in the literature (Gawronski & Bodenhausen, 2011; Jones et al., 2009; Mitchell et al., 2009). Besides theoretical advances of the effects of ageing on emotional memory, this thesis hopes to contribute to the marketing (Fung & Carstensen, 2003) and the clinical literatures (Balota et al., 2000), helping older adults with their well-documented memory deficits.

Chapter 2: General methods

Before describing the empirical studies, the current chapter will briefly explain the neuroimaging measures used in the thesis and the general methodological approach. The chapter will begin by discussing the EEG signal and ERP calculations, followed by the specific procedures used in this thesis to analyse the neuroimaging data. Then, the chapter will describe the different tasks used in the thesis, and will also detail the general participants' eligibility criteria, stimulus material and data analyses. In this chapter, only the common methodology used in the experiments will be detailed and justified. The particular methods for each experiment will be described in the respective sections in chapters 3, 4 and 5. All the experimental procedures described in this thesis were approved by the UCL Research Ethics Committee.

The physics behind EEG

The method chosen for this thesis was the electroencephalogram (EEG). The reason for this is that it has an extremely good temporal resolution, allowing the precise study of the different stages of memory as they happen, such as the old/new effects (Jaeger & Parente, 2008; Luck, 2005). Another reason for choosing EEG was the study of prestimulus effects, which can be stronger in the final milliseconds before item onset (Gruber & Otten, 2010) and also requires the use of a measure with high temporal resolution. EEG was discovered almost 150 years ago by Richard Caton from the exposed brains of non-human animals. Fifty years later, Hans Berger was able to measure this brain activity from living humans and coined the term EEG. He also observed that the brain waves were different if the person was sleeping, awake or under anaesthesia (reviewed by Teplan, 2002). Today, EEG is an important non-invasive way of identifying the connections between the brain and the mind with a temporal resolution of milliseconds (Bluntschli, Maxfield, Grasso, & Kisley, 2015; Johnsrude & Hauk, 2005; Light et al., 2010; Teplan, 2002).

EEG refers to the pattern of variations in voltage over time recorded as the difference between two electrode sites on the surface of the scalp (Coles & Rugg, 1995; Johnsrude & Hauk, 2005). However, to truly understand what the EEG signal is, it is necessary to borrow definitions commonly used in Physics and electrical engineering. To start, voltage refers to the potential for electric current to go from one point to another point (Luck, 2005). This explains why it is necessary to have at least two electrodes in order to record EEG (Coles & Rugg, 1995). The next concept to define is electric current. In a battery, the negative pole has a higher concentration of electrons than the positive pole. That makes the electrons move from the negative to the positive pole, creating the current. In that case, current is defined as the amount of electrons that pass by a point in a determined time (Luck, 2005).

In the brain, neurons communicate with each other via electrical activity (Augustine, 2001). This activity is based on the flow of ions (electrically charged atoms) between the inside and the outside of a neuron. The neuron's membrane is usually negative in its resting state, but produces peaks of positive polarity in response to another neuron or external stimuli. This peak in positive polarity, called action potential, travels from the neuron body to the axon terminal, where it releases neurotransmitters that will reach the next cell and change its potential. The intensity of a neuron's response to a stimulus is reflected in the frequency of action potentials generated, and not in their amplitude, since action potentials are an all-or-none phenomenon. The change in the membrane potential of the cell that receives the neurotransmitters is called postsynaptic potential and makes the cell more or less likely to fire its own subsequent peak of positive polarity, transmitting information from one cell to another (Augustine, 2001).

Scalp electrodes are thought to only be able to register postsynaptic potentials, because the action potentials are too fast and usually not synchronised between different neurons. But even though the postsynaptic potentials last longer and are easier to be detected by scalp electrodes, they are still very small in magnitude. So, it is necessary that a sizeable population of neurons are active in synchrony and in parallel orientation (Bressler & Ding, 2006; Light et al., 2010; Luck, 2012). That way, their individual electrical fields add up to a detectable signal via volume conduction (Bressler & Ding, 2006; Light et al., 2010; Luck, 2012). Because different parts of the brain have neurons in different alignments, it is not possible to measure EEG from every brain area (Coles & Rugg, 1995; Teplan, 2002), and the recording usually represents activity from cortical pyramidal cells (Luck, 2005).

In the present studies, the EEG signal obtained from participants was analysed in the form of event-related potentials (ERPs). ERPs correspond to EEG changes time-locked to an event, such as a given stimulus presentation (Coles & Rugg, 1995; Johnsrude & Hauk, 2005; Keil et al., 2014; Light et al., 2010). In other words, ERPs represent changes in the electrical activity of the brain in response to an endogenous or exogenous event (Coles & Rugg, 1995; Luck, 2005).

Researchers in cognitive neuroscience aim to provide functional interpretations from ERPs in order to enhance understanding of cognitive functions and their relationship with the brain (Otten & Rugg, 2005). ERPs can be analysed on the basis of components, which have defined spatial and temporal distributions that are associated with specific experimental manipulations or cognitive functions (Coles & Rugg, 1995). To define an ERP component, a considerable amount of accumulated research must agree on its anatomical and functional features. When such prior knowledge is not available, ERPs are analysed based on their time course, amplitude and scalp distribution (Donchin, Ritter, & McCallum, 1978; Otten & Rugg, 2005). For that, the ERP waveforms in response to one experimental condition are compared with those elicited in another condition. If those waveforms differ, it can be inferred that the cognitive processes linked with the two experimental conditions also differ, either in timing, in strength or in scalp distribution (Otten & Rugg, 2005). For example, when measuring old/new effects in a recognition memory task, if the experimental conditions differ in an early time window and at frontal electrode sites but do not differ in a later time window at left-parietal electrodes, it is possible to infer that those two conditions elicit different familiarity mechanisms, but similar recollection mechanisms.

Here, it is important to highlight two caveats about ERP data. The first is that ERPs provide no direct information about which area within the brain gave rise to the activity that was recorded in the scalp. That is because the brain is a volume conductor and the electrical activity generated in one area can be recorded at a different scalp position and even at a different time point (Coles & Rugg, 1995; Luck, 2005). This is called the inverse problem, and happens because it is impossible to know which population of neurons gave rise to the activity picked up from the scalp site, since an infinite number of combinations of dipoles could lead to the same pattern of activity (Luck, 2005; Woodman, 2010). The second caveat about ERPs is actually an issue with all neuroimaging techniques, named the reverse inference. It is logically valid to use psychological tasks to analyse how brain activity responds, but not the other way around. In other words, reverse inference is the process by which the engagement of a particular cognitive function is assumed, based on the pattern of brain activity that is observed (Poldrack, 2006). Unless this is based on a likelihood approach following an extensive literature review, reverse inferences are considered fallacious because they do not consider that that particular brain activity may be caused by another psychological process than the one being studied (Machery, 2014). In other words, there may not be a one-to-one correspondence between the observed pattern of brain activity and the cognitive function or process of interest.

Returning to the comparison between the ERPs elicited by two or more experimental conditions, the waveforms may differ in distinct features. According to Otten and Rugg (2005), the timing of the differences indicates when and for how long the cognitive processes in each condition are distinguishable. The strength of the differences is reflected in the amplitudes of each waveform, indicating quantitative differences in the cognitive processes related to each condition. Lastly, differences in scalp distribution reflect qualitative distinctions between the functional processes engaged in the conditions. When describing ERP effects, one will usually state the polarity of such effects, i.e. whether the waveforms in one condition are more positive- or negative-going than the ones in another condition. These designations are in accordance with the baseline, reference and ground chosen for the experiment. With enough prior knowledge, this information can be used to differentiate cognitive processes in a qualitative manner. However, the polarity of an ERP effect on its own provides little insight, since it can be influenced by the location and orientation of intracerebral sources (Otten & Rugg, 2005).

ERP analyses in this thesis

The procedures for participant preparation, capping and impedance checking were done in accordance with common procedures used for EEG studies, reviewed by Keil et al. (2014).

EEG was recorded from 42 sintered silver/silver-chloride electrodes embedded in an elastic cap following an equidistant montage (see Figure 2.1, http://www.easycap.de/e/electrodes/13_M10.htm). (Experiment 3.1 had 38 electrodes. The number of electrodes was increased after the first experiment to provide a more comprehensive cover of the scalp. However, the additional four electrodes were not used on any analyses in this thesis). The cap size was chosen based on each participant's head circumference and the cap was held in place by chest belts. The recording was done in a room with temperature held relatively constant in order to avoid perspiration. Four electrodes, located on the supraorbital and infraorbital ridges of the right eye and on the outer canthus of each eye, were used for bipolar registration of vertical and horizontal eye movements respectively (Luck, 2005). A fronto-central electrode site was used as the ground electrode. A mid-frontal site was used as online reference, while two mastoid electrodes were measured and later used for offline re-referencing (Keil et al., 2014). The ground electrode is a common point to which the static energy of the participant's body is discharged so it does not cloud the neural signal. To eliminate electrical activity picked up from the environment, the voltage between the electrodes of interest and the reference electrode is subtracted from the voltage between the electrodes of interest and the ground electrode (Luck, 2005). The mastoids were chosen for being areas relatively unaffected by the brain activity of interest in the studies, but equally affected by global voltage changes, such as respiration. The re-referencing of the EEG signal computes the difference in voltage between each electrode of interest and the linked mastoids (Coles & Rugg, 1995; Johnsrude & Hauk, 2005; Luck, 2012; Teplan, 2002).

Impedances – the resistance to passage of electrical current (Luck, 2005) – were kept below 5kΩ by using conductive gel applied with needleless syringes, and wooden sticks for scraping the scalp, done to decrease the level of noise in the signal (Bressler & Ding, 2006; Teplan, 2002). Online, signals were amplified (DC amplifiers, Brain Products GmbH), bandpass (high- and low-pass) filtered between 0.016 and 250Hz and digitized at a rate of 1000Hz (the number of samples taken per second, which must be more than two times the highest frequency in the signal) with a 16-bit resolution (i.e. the equipment was able to digitise 2^{16} different voltage values). The online filters make sure that the frequency of the signal does not exceed the amplifier capability. The amplification and digitization are necessary because of the small (microvolt) signals and to allow analog EEG signals to be analysed and stored on a computer (Johnsrude & Hauk, 2005; Luck, 2012; Teplan, 2002).

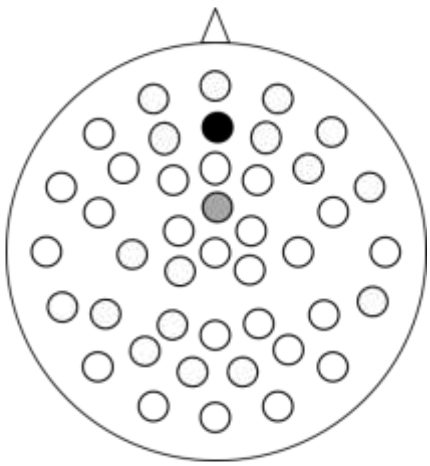

Figure 2.1. Recording electrode sites.

Schematic illustration of the 42 recording electrode scalp sites used in experiments 3.1, 3.2 and 5.3. The black-filled circle represents the online reference, and the grey-filled circle represents the electrode used as ground.

The BrainVision Analyser (Brain Products GmbH) software was used to pre-process the EEG data and compute ERPs. Offline, continuous data were digitally filtered between 0.05 and 20Hz with a 48dB/Oct roll-off to eliminate electrical activity that will definitely be too high or too low to be of interest to the ERP effects measured in this thesis (Bressler & Ding, 2006; Coles & Rugg, 1995; Johnsrude & Hauk, 2005; Teplan, 2002). Ocular artefacts are usually present with the same frequency as the ERPs of interest, thus, filtering is not able to eliminate them (Coles & Rugg, 1995). An Independent Component Analysis, ICA, (Delorme & Makeig, 2004; Hoffmann & Falkenstein, 2008) was used to minimise the contribution of eye movements and blinks from the overall signal. This was done in a semi-automatic manner, that is, the software algorithm (fast track ICA, BrainVision systems) detected the different components in order of their contribution to the general signal and suggested which ones were caused by eye movements. Then, I visually inspected those components for the patterns of activity displayed in the scalp maps and either accepted or rejected the suggestions for deleting the components. In brief, components due to blinking usually show a strong positive activity at frontal sites and a negative activity at posterior sites. Side eye movements usually elicit opposite polarities at left and right frontal electrode sites.

Continuous data were divided into 2300ms epochs surrounding cues and images/words, beginning 100ms before their onset. As mentioned before, the brain activity elicited within those epochs in response to a given set of stimuli is what is called the ERPs (Coles & Rugg, 1995). Drifts, eye movements and muscle activities were rejected from segments in which activity surpassed -100 µV or 100 µV. Segments were aligned (i.e. baseline corrected) to the 100ms period before cue and picture onsets. This was done to ensure that only activity in response to the experimental manipulations is analysed (Johnsrude & Hauk, 2005; Keil et al., 2014). The data were, finally, re-referenced to linked mastoids and the mid-frontal online reference site was reinstated.

After this initial processing was done, it was necessary to separate the actual ERP signal from noise still present in the individual epochs. This was done by averaging the trials according to the categories being analysed, that is, the experimental conditions. The averaging works because the activity that is generated in response to that particular category of stimuli in different trials will be maintained, whereas the other types of activity will be random and tend to average out (Bressler & Ding, 2006; Coles & Rugg, 1995; Johnsrude & Hauk, 2005; Luck, 2012; Teplan, 2002). In this thesis, only participants who had at least 12 artefact-free trials (cf. Galli et al., 2011) for the categories of interest were used in the ERP and behavioural analyses. This is on the low side of trials that are sufficient to calculate ERP effects with reliability.

ERP waveforms were quantified by averaging amplitudes in a given time window, which is called mean amplitude. This method offers many advantages such as being less sensitive to extreme-frequency noise and allowing a more direct comparison with the statistical results since it is a linear measure (Luck, 2005). To conclude if an ERP effect is statistically significant, its amplitude is contrasted in an ANOVA according to time windows, scalp regions and memory accuracy as within-subject factors (Johnsrude & Hauk, 2005). The temporal parameters varied according to the experimental aims of each study, as did the other factors (e.g. age group or emotional valence). These details are explained for each experiment in the respective methods sections.

The spatial parameters were kept constant throughout the thesis, and can be seen in Figure 2.2 for Dm effects and old/new effects. Greenhouse-Geisser corrections were applied whenever necessary to the global and subsidiary ANOVAs to avoid Type 1 errors (Keil et al., 2014). Data were interpreted according to significant main effects and interactions between factors, considered as *p*-values lower than 0.05. The interactions were decomposed by looking at each time window or experimental condition individually.

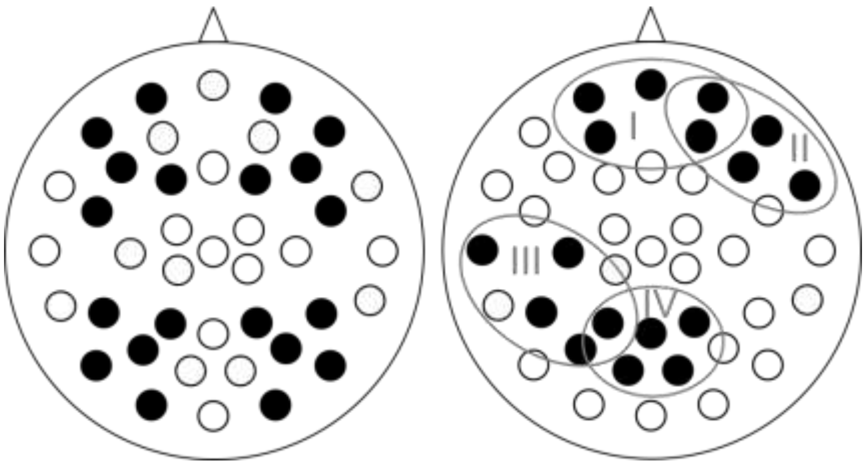

Figure 2.2. Electrode sites used in the encoding and retrieval analyses.
Schematic representation of electrode sites used in the encoding and retrieval analyses in this thesis (filled sites) in the entire array of channels recorded (white sites). Left: Electrodes used for encoding analyses were divided into anterior/posterior and left/right. Right: Each old/new effect during retrieval was analysed using specific areas. I: mid-frontal effect, II: right-frontal effect, III: left-parietal effect, IV: late posterior negativity effect.

Behavioural tasks and measures

Encoding

In the encoding task used in experiments 3.1 and 3.2, each stimulus was presented one at a time. Participants were required to make indoor/outdoor judgments for each image presented. Schematic facial cues preceded each image and indicated the valence of the upcoming image. The proportion of indoor/outdoor responses and the response time for the decisions were statistically contrasted according to the specific manipulations in each experiment.

In experiments 4.2, 5.1, 5.2 and 5.3, the encoding task consisted of words being presented one at a time. Participants were asked to create sentences with those words according to the cue that preceded each of them. Participants should also press a key on the response box to indicate when the sentence was completed. This was done to ensure participants were paying attention to the task, especially in experiment 5.1, when the sentences should not be spoken out loud. The response time was compared according to the conditions and manipulations of each experiment and used as a rough measure of how long it took participants to create the sentences.

Retrieval

This thesis used recognition memory tasks to investigate episodic memory. As detailed in Chapter 1, episodic memory is composed of two components – familiarity and recollection (Yonelinas, 2002) – with different characteristics and brain correlates (Eichenbaum et al., 2007; Moscovitch et al., 2006; Squire et al., 2007).

Different types of task can be used to tap into familiarity and recollection. Experiments 3.1 and 3.2 of this thesis utilised the remember/know procedure (Eichenbaum et al., 2007; Tulving, 1985). In this procedure, participants are asked to decide if they subjectively remember specific details about the time of encoding ("remember"), if they simply feel that the item is old ("know"), or if they think the item is new. "Remember" judgments would be more based on recollection and "know" judgments, more on familiarity (Migo et al., 2012; Yonelinas, 2002), although both processes contribute to the two judgments to different degrees.

Experiments 4.2, 5.1, 5.2, and 5.3 used a source memory task, which is an objective way of measuring recollection. This was chosen because, in those studies, the main goal was to investigate the encoding/retrieval of emotional context specifically, and not any type of context, as would be the case in a remember/know procedure. Additionally, previous literature looking into the brain activity during retrieval of neutral information encoded in an emotional context advocates for the use of source memory tasks rather than remember/know tasks, because they specifically ask participants to recall the emotional context and not any context, eliciting specific emotion-related brain activity (Maratos & Rugg, 2001; Smith, Dolan, et al., 2004). In the source memory procedure, participants are asked to decide if an item is old or new and, if old, what contextual information was associated with it during encoding (Squire et al., 2007). When the source is remembered, participants are thought to have used recollection; when only the item is recalled, they have instead used familiarity (Eichenbaum et al., 2007; Yonelinas, 2002). It is important to highlight that a comparison of the remember/know method and the source memory method done by Donaldson, MacKenzie, and Underhill (1996) showed they produce highly similar behavioural results, which further supports that both remember/know/new and source-memory tasks are powerful tools to look into recollection and familiarity. Importantly, literature suggests that old/new effects of "remembered" items in remember/know tasks and of "source hits" in source memory tasks are qualitatively and quantitatively similar (Mark & Rugg, 1998).

To analyse memory performance in this thesis, a discrimination index according to the Two-High Threshold Model (Snodgrass & Corwin, 1988) was used. This model predicts that the hit rate, i.e. the proportion of old items given a correct old judgment, is composed of truly recognised items plus some lucky guesses. The discrimination index Pr is, in turn, calculated as the difference between the proportion of truly remembered items and new items given an remember judgment (called "false alarms"), thus [Pr = p(Remember Hits) – p(Remember False Alarms)]. Some participants will be more liberal or more conservative when giving old responses to items they are uncertain of. This tendency can be measured by the response bias index Br, with takes into account the False Alarm Rate and also the proportion of old items that failed to be recognised. Therefore, Br = Remember False Alarm Rate / (1 – Pr remember). A higher Br value indicates participants with more liberal decisions in that particular task or trial and a lower Br value suggests participants that needed certainty to give an old judgment in the same task. Additionally, an index of familiarity was calculated [Fam = p(Know Hits)/(1-p(Remember Hits))], adjusted for false alarm rates (Friedman et al., 2010).

In experiments 4.2, 5.1 and 5.2, Pr and Br were calculated for items that received a "source hit" judgment. Pr and Br measures in all studies were statistically tested with an ANOVA with between- and within-subject factors that varied according to each experiment.

For all behavioural analyses, greenhouse-Geisser corrections were applied whenever necessary (Jennings & Wood, 1976). When pairwise comparisons were used, Bonferroni corrections were applied.

Likeability

Experiments 4.2, 5.1 and 5.2 employed a measure of likeability, since it was investigated whether the neutral stimuli had acquired emotionality via evaluative conditioning (Jones et al., 2010). The main statistical analyses of the likeability ratings compared average ratings given to items used in a positive context and in a neutral context, as well as other between- and within-subjects factors according to each experiment's manipulations. The ratings were contrasted using ANOVAs.

Effect size

In this thesis, effect sizes are reported for behavioural and ERP data by calculating the partial eta squared values. This measurement was chosen because it is the one mostly used in psychological research with different experimental designs (Richardson, 2011). The effect was calculated by the formula η^2_p = SSeffect / (SSeffect + SSerror), where SS is the sum of squares, representing the variability in the dataset (Pinhas, Tzelgov, & Ganor-Stern, 2012). It is widely accepted in the literature that effect sizes are classified as small when between .0099 and .0588, medium when between .0588 and .1379, and large when above .1379 (Richardson, 2011)

Stimulus material

The tasks were programmed and the stimuli presented using Cogent2000 developed by the Cogent 2000 team at the FIL, and MATLAB 2013b (MathWorks, 2013). Part of the experiments used photographs as stimuli, and others used words. Most experiments also used preparatory visual cues. These materials will be detailed next.

Images

Experiments 3.1 and 3.2 used coloured photographs as stimuli. The images were selected from the International Affective Picture System created by Lang et al. (1997). The system depicts several types of scenes rated according to different dimensions of emotionality. The images used in this thesis were selected based on the dimensions of valence and arousal, which are the most important ones in terms of impact on memory performance (Bennion et al., 2013). In the IAPS norms, these dimensions are defined according to the feeling produced in participants when viewing the images on a scale from 1 to 9. Valence goes from "unhappy" to "happy", with images rated lower than 4 considered to reflect negative valence, images rated between 4 and 6 as reflecting neutral valence, and images rated higher than 6 as reflecting positive valence. The dimension of arousal is a continuum going from “very calm” to “very excited”. More recent norms for the IAPS (Gruhn & Scheibe, 2008) were used to select the images, since the levels of valence and arousal needed to be matched between younger and older participants. The images were presented in the middle of the screen against a solid black background with a visual angle of 6.3° vertically and 4.75° horizontally.

Words

Experiments 4.1, 4.2, 5.1, 5.2 and 5.3 used visual words as stimuli. They were all nouns selected from the database created by Ghent University (http://crr.ugent.be/). All selected words were rated neutral (4 to 6 on the valence scale) by both younger and older adults (Warriner, Kuperman, & Brysbaert, 2013). Additionally, selected words were rated as at least 3 (out of 5) in concreteness (Brysbaert, Warriner, & Kuperman, 2014), had two syllables and were between four and eight letters, and presented a frequency in the English language of between 3 and 4 (out of 7) on the logarithmic Subtlex scale (van Heuven, Mandera, Keullers, & Brysbaert, 2013). For each experiment, the total number of words was separated into lists counterbalanced across conditions and participants. Those lists were carefully matched according to the criteria described above and also to arousal levels and frequency in the English language on the Celex scale (van Heuven et al., 2013; Warriner et al., 2013). Words were presented in the middle of the monitor screen, in white Helvetica font size 30, against a solid grey background. The cues preceding each word during the study phase were schematic happy and neutral faces.

Cues

In experiments 3.1, 3.2, 4.2, 5.1, 5.2 and 5.3 stimuli were preceded by cues that indicated the valence of the upcoming item. These cues were schematic sad, happy or neutral black and white faces (Figure 2.3), presented in the centre of the monitor with a visual angle of 1.4° horizontal and 1.4° vertical (cf. Galli et al., 2011).

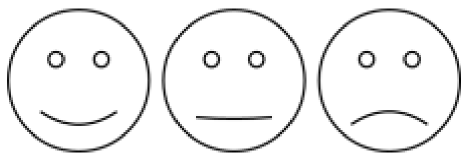

Figure 2.3. Facial cues.

Representation of visual cues used in experiments 3.1, 3.2, 4.2, 5.1, 5.2 and 5.3 representing positive, neutral and negative expressions.

Participants

The younger adults that took part in the experiments described in this thesis were recruited from university databases, specifically those of the Institute of Cognitive Neuroscience research department and the Psychology and Language Sciences Division. The older adults tested in experiments 3.1, 5.1, 5.2, and 5.3 were mostly recruited from the University of the Third Age and the Mary Ward Centre. Those two organisations provide classes and courses to older residents of London. A minor portion of the older participants were friends and family of the ones that had already been part of the experiment. Younger and older participants were compensated at the rate of £7.50/hour or received university course credits. Before any procedure took place, participants were given an information sheet detailing the experimental procedures and allowed to ask questions. They then provided written informed consent. At the end of an experimental session, participants were debriefed, thanked and paid for their time.

Eligibility criteria

A few criteria were used when selecting participants for experiments in this thesis. Participants needed to be English native speakers and not taking psychotropic medication or licit/illicit drugs in the 24 hours before the session. They also did not have a history of neurological or psychological illness, or over-sensibility to negative emotions. The information about their psychological history was provided by participants themselves. For the ERP experiments (3.1, 3.2 and 5.3), participants should also be right-handed.

Mood questionnaires

In this thesis, a few mood questionnaires were administered to participants. In Chapters 3 and 5, anxiety and depression questionnaires were chosen because the experiments revolved around emotional memory. Literature has shown that people with high scores on anxiety (Etkin & Wager, 2007; Lang et al., 1998) or depression (Davidson, Pizzagalli, Nitschke, & Putnam, 2002; Drevets, 2001) show behavioural and brain activity differences compared to healthy controls. Thus, the scores obtained in those questionnaires were compared between younger and older participants to ensure no group differences in anxiety and depression. The specific questionnaires chosen to assess anxiety and depression were the State-Trait Anxiety Inventory (STAI), the Beck Depression Inventory-II (BDI-II) and the Geriatric Depression Scale (GDS). Each of them will be explained in more detail next.

The STAI (Spielberger, Gorsuch, & Lushene, 1970) consists of two parts. Each part is composed of 20 questions that should be answered on a 4-point scale. The State part measures the anxious state of a participant at that exact time and, thus, can vary within-subjects from situation to situation. The questions should be answered according to the degree to which each statement is currently felt by the participant. The Trait part measures a more stable personality trait, affecting people's decisions and perceptions of the world. The answers refer to how often that statement is felt by participants in their daily lives. The minimum score in each part of the questionnaire is 20 and the maximum is 80. Younger participants are considered "normal" when scoring below 39, and older participants, below 54 (Julian, 2011; Kvaal, Ulstein, Nordhus, & Engedal, 2005).

The BDI-II (Aaron T Beck, Steer, & Brown, 1996) is a frequently used instrument to evaluate depression symptoms in patients and the general population. It consists of 21 multiple-choice questions representing different symptoms of depression. The accepted cut-off scores for this test are lower than 10 for not depressed participants, 10-18 for mildly depressed participants, and more than 18 for clinically depressed participants (Aaron T. Beck, Steer, & Carbin, 1988; Aaron T. Beck, Ward, Mendelson, Mock, & Erbaugh, 1961).

The GDS (Yesavage & Sheikh, 1986) is satisfactorily sensitive to depression in the ageing population (Jongenelis et al., 2005). It consists of 15 yes-or-no questions regarding how participants felt during the past week. The scores can range from 0 to 15. Scores higher than 5 are suggestive of depression and scores higher than 10 almost always mean that a participant is clinically depressed (Yesavage & Sheikh, 1986).

Chapter 4 tested participants' natural tendency to attribute positive emotions to neutral information. Thus, a different set of mood questionnaires was used to correlate personality traits with the behavioural measures of the experiment. This was done because previous literature shows that personality traits have a significant impact on emotion regulation, as detailed in the introduction of experiment 4.1. The chosen tests were the Rosenberg Self-Esteem scale and the Big Five personality inventory.

The Self-esteem scale (Rosenberg, 1965) consists of 10 questions to be answered on a 4-point Likert scale as "strongly disagree – disagree – agree – strongly agree", and measures participants' overall sense of worth as an individual. Although it was initially developed to be applied to adolescents, the scale has since been validated for younger and older adults as well (Sinclair et al., 2010).

The Big Five Personality Inventory (John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008) is the most widely used questionnaire to assess different personality traits. It consists of 43 statements to be answered on a 5-point Likert scale according to “disagree strongly” to “agree strongly”. This inventory has successfully been used with older adults (Specht, Egloff, & Schmukle, 2011). As the name of the inventory suggests, participants are scored on five subscales: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. A brief description of each trait is obtained from John and Srivastava (1999): Openness refers to the depth, originality and complexity of someone’s life. Conscientiousness refers to how a person controls their impulses in order to follow the rules, and plan, organise and prioritise tasks. Extraversion includes being sociable, active, assertive and positive towards the world. Agreeableness refers to prosocial behaviour such as altruism, tender-mindedness, trust and modesty. Neuroticism describes how much one feels anxious, nervous, unstable, sad and tense. For the computations, the score on the questions relevant to each trait were averaged. Thus, participants receive a mean score ranging between 1 and 5 for each of the five traits.

Chapter 3: Effects of emotion on memory-related brain correlates in younger and older adults

Experiment 3.1: Encoding and retrieval of emotional memory in the ageing brain

The results of this experiment have been submitted as a research paper to the journal Social Cognitive and Affective Neuroscience, which is currently under review.

Introduction

This study was based on the paper by Galli et al. (2011). These authors analysed encoding-related ERP activity before and after stimulus onset in younger adults as a function of the stimulus' emotional valence. Brain activity after stimulus onset showed a anteriorly-distributed positive-going Dm effect but did not differ between the three emotional valences. However, the prestimulus Dm effect was only present before negative images. This effect was also positive-going, but maximal on the right hemisphere and present for the entire analysed epoch. The authors explained these findings by the stronger evolutionary importance of negative events (Dolan, 2002). Such events usually represent threatening circumstances that could affect survival and reproductive success. Anticipatory mechanisms would manage one's expectations of negative events, enhancing memory for those events, and allowing a better and prompter response in the future.

A stronger anticipatory encoding mechanism for negative events in younger adults fits the Negativity Bias hypothesis. As explained in Chapter 1, this hypothesis states that younger adults focus their attention primarily on negative events and therefore remember those better than positive ones (Baumeister et al., 2001; Rozin & Royzman, 2001). However, according to the Socioemotional Selectivity Theory (Carstensen et al., 1999), ageing shifts these attentional and memory processing towards positive information, in the so-called Positivity Effect (Carstensen & Mikels, 2005). It is possible that this shift towards positive emotions in older adults is partially related to stronger anticipatory brain mechanisms. That is, while younger adults prepare for negative events, older adults show preparation for the positive ones. It is also possible, however, that the Positivity Effect is related to a later memory process. Thus, younger and older adults may deploy preparatory mechanisms to negative events, because of the evolutionary importance of those events, but older adults may show stronger post-stimulus encoding-related activity or retrieval-related activity in response to positive events. Because, to my knowledge, no study so far has looked into prestimulus Dm effects in older adults, the aim of the current study was to test how such effects are influenced by the interaction between ageing and emotion.

This study virtually reproduced Galli et al. (2011)'s methodology with a few adjustments to the presentation parameters due to the older age of participants. Negative, neutral and positive IAPS images were preceded by schematic facial cues that indicated the upcoming valence. The encoding phase was incidental and followed by a remember/know recognition memory task 20 minutes later. Following from the Positivity Effect, it was predicted that younger adults would show a prestimulus Dm effect for the negative condition, whereas older adults would show it for the positive condition. It was also predicted that post-stimulus encoding activity would be stronger for emotional items (positive and negative) when compared to neutral images. In relation to retrieval, it was predicted that older adults would show lower memory performance and weaker left-parietal effect.

Methods

Participants

Seventy-one female participants volunteered for this study (Young Adults [YA], n = 38, mean age = 21.1±1.9 years, and Older Adults [OA], n = 32, mean age = 70.7±7.1 years). 1 YA and 1 OA were excluded from the analyses for showing a below-chance performance on the memory task, defined as a negative Pr (see Chapter 2). Only females were tested in this experiment due to previous literature suggesting that the prestimulus encoding Dm effect is only affected by emotion in women (Galli et al., 2011). Participants completed the state-trait anxiety inventory (Spielberger et al., 1970), the Beck Depression Inventory (Aaron T. Beck, 1967) for YA, and the Geriatric Depression Scale (Yesavage & Sheikh, 1986) for OA, as explained in Chapter 2.

Stimuli

The experimental stimuli were IAPS images of positive, neutral and negative scenes. Pictures that had similar valence and arousal ratings in YA and OA were chosen (Gruhn & Scheibe, 2008), thus not all images used in the current study were the same as the ones used by Galli et al. (2011). Specifically, 7% of the negative images were different, 14% of neutral images, and 25% of positive images differed between the two studies. The higher amount of difference in the positive category was due to the removal of all erotic images, since those usually show stronger age-related differences in valence or arousal ratings (Gruhn & Scheibe, 2008; Schultz, de Castro, & Bertolucci, 2009). Positive and negative scenes were matched for arousal (independent sample t-test, t(169) = 1.514, p = .132) and were both more arousing than neutral pictures (t(169) = 23.592 and 26.282, respectively, p < .001 for both). One hundred seventy pictures of each emotional valence were chosen: five were used during the practice sessions and the remaining were split into three groups of 55, two of which were used as old items and one as new items. The way in which each picture group was assigned to each category was counterbalanced across participants. For the study task, old items were randomly allocated to a study list composed of 330 items (110 for each emotional valence) divided into five blocks. The test list consisted of those old items plus 165 new items (55 of each emotional valence), all randomly allocated and divided into eight blocks. A new randomization was made for each participant.

Procedure

Before the task began, participants were capped and connected to the EEG equipment (see “EEG acquisition and analyses”).

The experimental session was divided into a study phase, composed of an incidental encoding task, and a test phase, which consisted of a recognition memory test (Figure 3.1.1). In the study phase, participants viewed a series of negative, positive or neutral images presented one at a time. These images were preceded by a schematic sad, happy or neutral face, respectively, which served as a cue to indicate the emotional valence of the upcoming image. The instructions for the task emphasized that participants should use the cues to prepare for the following image. Participants had to make an indoor/outdoor judgment for each image using the response box (thumb and little fingers, counterbalanced across participants). Before the beginning of the study phase, all participants completed five practice trials. In those trials, they were required to justify why they had chosen “remember” or “know”. With this, I could judge whether participants had properly understood the differences between the two judgments. A ~20 minute break followed the end of this task, when participants completed the mood questionnaires.

The test phase consisted of a remember/know recognition memory task (Tulving, 1985), chosen to allow a more thorough investigation of processes of recollection and familiarity. Each image was preceded by the same schematic facial cues used in the study phase to indicate its emotional valence, in order to maintain the two tasks as similar as possible and not elicit specific brain activity that could interfere with the main results. Participants were instructed to indicate, using the response box (index, middle, and ring fingers of the right hand, counterbalanced across participants), whether they “remembered” the image, “knew” the image, or if they thought the image was “new” (did not see the item in the previous task, or was not sure of the answer). At the end of the test phase, participants answered demographic questions (age, sex, first language, occupation, highest educational degree, and years of formal schooling) and debriefing questions that would inform about how they approached the tasks. Participants were then thanked, debriefed, paid, and had the EEG cap removed and the hair washed.

OA tested in a pilot study reported not being able to complete the task because the presentation times used in Galli et al., 2011 for cues and pictures were too quick. Thus, those settings were expanded to 1900ms for cue presentation, followed by 100ms of a black screen, and then a picture that remained on the screen for 2000ms. The time in between trials varied from 3000 to 4500ms, during which time a white fixation cross was shown. The total time of the session, including EEG preparation was around 3,5 hours.

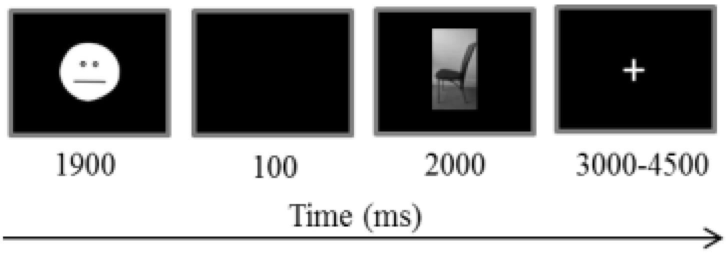

Figure 3.1.1. Trial sequence during the encoding and retrieval phases.
During the encoding phase, participants made indoor/outdoor judgments for each image. During the retrieval phase, participants judged if images were old or new using remember/know/new responses.

EEG measures

The procedures for acquisition and processing of the EEG signal can be found in Chapter 2.

Twenty four YA and 24 OA had the minimum number of artefact-free trials and were the ones used in the analyses. The mood questionnaire scores and the behavioural performance scores let to similar statistical results whether the analyses were done with 69 or 48 participants. Therefore, only the latter are presented in the results section. Remembered items were defined as old items correctly identified with a remember judgment. Forgotten items were defined as old items misclassified as new by the participant. “Know” judgments were not included in the analyses due to low trial numbers and to previous research suggesting that the effects of depth of processing and of prestimulus activity are more prevalent for recollection (Gruber & Otten, 2010; Otten et al., 2006; Rugg, Walla, et al., 1998). The mean and standard deviation for the number of trials the ERP analyses can be seen in Table 3.1.1.

ERPs were calculated for each participant and each electrode site according to the emotional valence and the recognition memory judgement given to each image. Thus, in the study phase, each segment was classified as positive/negative/neutral and as remembered/known/missed. Thus, the study phase was analysed according to Dm effects calculated as the difference between activities elicited by later “remembered” and later “missed” items. This calculation was done separately for prestimulus (after cue onset) and post-stimulus (after image onset) activity (Otten et al., 2006). The retrieval phase was examined according to old/new effects, which are the difference between activity elicited by remembered items and correctly rejected items.

Table 3.1.1. Mean trial numbers used in the ERP analyses.

			Younger adults	Older adults
Encoding, prestimulus	Positive	Remember Hits	47.6 (15.7)	49.0 (19.3)
		Misses	26.0 (10.4)	29.2 (13.7)
	Negative	Remember Hits	53.6 (17.8)	51.5 (19.2)
		Misses	24.3 (12.5)	28.5 (14.7)
	Neural	Remember Hits	48.3 (19.7)	53.1 (19.1)
		Misses	25.0 (9.8)	30.8 (14.2)
Encoding, post-stimulus	Positive	Remember Hits	47.5 (16.9)	48.0 (19.4)
		Misses	25.2 (10.3)	29.4 (14.3)
	Negative	Remember Hits	52.4 (19.0)	50.7 (20.2)
		Misses	25.7 (13.4)	28.3 (14.7)
	Neural	Remember Hits	49.8 (19.6)	52.7 (20.1)
		Misses	25.3 (10.8)	30.8 (14.4)
Retrieval	Positive	Remember Hits	45.2 (16.6)	48.0 (19.9)
		Correct Rejections	36.8 (9.3)	37.1 (8.2)
	Negative	Remember Hits	50.4 (18.5)	50.6 (21.3)
		Correct Rejections	38.9 (9.1)	36.5 (9.5)
	Neural	Remember Hits	46.3 (19.5)	51.9 (21.2)
		Correct Rejections	40.5 (10.0)	42.3 (9.4)

The numbers in parentheses are standard deviations.

Behavioural and EEG analyses

Details of behavioural measures Pr and Br can be found in Chapter 2. Pr and Br values were submitted to a mixed-model ANOVA with age as a between-subject factor and emotional valence as a within-subject factor. ERP waveforms were contrasted according to the valence of the picture (positive/negative/neutral), the accuracy during the memory test (remember hits/misses/correct rejections), and the interaction of these factors.

For the encoding data, the ERP epoch was divided into three time windows in order to verify differences across time. For prestimulus encoding-related activity, the chosen time windows were 200-800ms, 800-1400ms, 1400-2000ms; for post-stimulus encoding related activity, time windows were 200-600ms, 600-1000ms, 1000-1400ms. These time windows were chosen based on previous literature (Galli et al., 2011), but enlarged because ERP effects are generally delayed in OA (Morcom & Rugg, 2004; Zanto et al., 2010). The use of three equal-duration intervals before and after image onset allows the assessment of how brain activity changes over time. Scalp electrodes were divided into four areas of five electrodes each (see details and Figure 2.2 in Chapter 2) in order to analyse for differences across scalp areas (Galli et al., 2011). Thus, ERP encoding data from the 20 selected electrode sites were submitted to a mixed-model ANOVA with within-subjects factors of location (frontal/posterior), hemisphere (left/right), time window, subsequent memory (remember hits/misses), emotional valence (positive/negative/neutral), and between-subject factor of age group (younger/older).

For the retrieval data, the chosen time windows were the ones that usually capture the three old/new effects: 300-500ms, 500-800ms, and 800-1200ms (Curran, 2000; Curran & Cleary, 2003; Migo et al., 2012; Schefter, Knorr, Kathmann, & Werheid, 2012; Woodruff et al., 2006). For each time window, five electrodes on the scalp region where the relevant effect has been demonstrated to be maximal were selected and averaged (see Figure 2.2). Analysis of retrieval data was done specifically for each time window and scalp region and had only remember hits/correct rejection status, emotional valence and age group as factors for the ANOVA.

Results

Mood questionnaires

YA and OA did not differ in their scores for most of the mood questionnaires (Table 3.1.1). YA's score on the BDI and OA's score on the GDS were among the normal range (Almeida & Almeida, 1999; Bumberry, Oliver, & McClure, 1978).

Table 3.1.2. Mean scores on the mood questionnaires.

	Young adults	Older adults	Statistical comparison
Depression	6.3 (5.1)	1.9 (2.0)	-
Anxiety trait	36.2 (8.6)	36.5 (10.4)	t(46) = -.106, p = .916
Anxiety state	31.4 (7.9)	29.2 (7.2)	t(46) = .973, p = .336

The numbers in parentheses are standard deviations.

Behavioural performance

In the study task, the proportion of indoor/outdoor responses was not influenced by ageing, $p > .057$. However, it differed depending on the valence of the image (F(1.437, 66.099) = 439.283, $p < .001$, $\eta^2_p = .905$). Pairwise comparisons revealed that more indoor judgments were made to neutral than negative and positive images, and to negative than positive pictures, $p < .001$.

Mean response time for each type of judgment for positive, negative, and neutral images was compared in a mixed-model ANOVA with age group as a between-subjects factor. Results revealed a main effect of valence (F(2,92) = 68.626, $p < .001$, $\eta^2_p = .599$), a main effect of type of judgment (F(1,46) = 50.173, $p < .001$, $\eta^2_p = .522$) and an interaction between the two factors (F(1.625,74.751) = 24.348, $p < .001$, $\eta^2_p = .346$). When looking at each type of judgment individually, pairwise comparisons showed differences between all pairs of images ($p < .002$). Negative images were responded to more slowly than positive images. However, neutral images elicited the quickest indoor response, and the slowest outdoor response. These results indicate that it was easier to identify neutral images in indoor scenes, and emotional images in outdoor scenes. A main effect of age was found, with OA being slower than YA (F(1,46) = 7.655, $p = .008$, $\eta^2_p = .143$).

As explained in the methods section, performance in the test phase was analysed based on the discrimination index Pr and the response bias Br (Table 3.1.2). The same mixed-model ANOVA used for the study phase was used here.

Table 3.1.3. Memory performance (%) of younger and older adults for positive, negative and neutral images.

	Younger adults			Older adults		
	positive	negative	neutral	positive	negative	neutral
Old items						
Remember	46.5(14.7)	51.7(16.5)	48.1(18.1)	47.4(18.4)	49.6(19.0)	51.8(19.3)
Know	27.4(12.3)	24.3(13.1)	27.2(14.9)	23.7(14.7)	22.2(14.8)	18.3(13.8)
Miss	25.4(10.2)	23.5(11.8)	24.4(10.3)	28.4(12.2)	27.6(12.9)	29.5(12.7)
New items						
CRej	76.0(13.4)	79.4(11.6)	82.5(11.1)	80.0(11.6)	72.2(14.0)	82.0(11.6)
FA	23.6(13.4)	20.4(11.6)	16.9(11.3)	26.9(11.8)	27.3(14.0)	17.4(11.8)
Indices						
Pr Rem	.42(.14)	.47(.17)	.45(.17)	.40(.16)	.41(.17)	.47(.19)
Br Rem	.09(.07)	.10(.08)	.07(.08)	.14(.12)	.16(.13)	.10(.10)
Fam	.30 (.15)	.33 (.18)	.36 (.17)	.22 (.14)	.21 (.14)	.22 (.14)

Numbers in parentheses are standard deviation. CRej = correct rejections; FA = false alarms; Pr = discrimination index for remember judgments; Br = response bias for remember judgments; Fam = familiarity index. Data after exclusion of no-response trials.

For Remember judgments, index Pr showed a main effect of valence ($F(2,92) = 5.362$, $p = .006$, $\eta^2_p = .104$), no effect of age, $p = .721$, and an interaction between valence and age ($F(2,92) = 3.236$, $p = .044$, $\eta^2_p = .066$). Pairwise comparisons revealed that YA performed better with negative than positive images, $p = .024$. These results need to be taken with caution because there were no statistical difference between positive and neutral, $p = .245$, or negative and neutral, $p = .361$, images. OA performed better with neutral images compared to positive, $p = .001$, and negative, $p = .026$, images. Positive and negative images did not differ from each other, $p = .494$. When comparisons are done between YA and OA for each valence, no significant results emerge ($p > .296$).

Index Br for Remember judgments showed a main effect of valence ($F(2,92) = 6.813$, $p = .002$, $\eta^2_p = .129$), no main effect of age, $p = .081$, and no interaction between the factors, $p = .325$. Neutral pictures elicited a smaller response bias than both positive, $p = .009$, and negative, $p = .001$, images, which did not differ between each other, $p = .325$.

Regarding familiarity, valence showed no effect, p = .341 nor an interaction with age, p = .354. A main effect of age was found, with YA having a greater index than OA (F(1,46) = 8.058, p = .007, η^2_p = .149).

In summary, index Pr in the memory task depended on the interaction between emotional valence and age group, with OA showing better memory for neutral images and YA for negative images. Response bias was more liberal for emotional images.

Prestimulus Dm effects

Prestimulus Dm effects did not seem to be affected by either age or valence, taking the form of a long-sustained positivity at right-posterior scalp sites. The statistical analyses (described next) confirmed this result and so, Figure 3.1.2 shows the grand average and topographic maps of prestimulus Dm effects for each valence and age group.

As explained in the Methods section, encoding prestimulus Dm effects were quantified in three selected time windows (200-800, 800-1400, 1400-2000 ms) and ERP amplitudes from 20 selected sites were submitted to a mixed-model ANOVA. None of the factors of interest – age and valence – interacted with memory in this ANOVA, p > .108. Interactions were found between subsequent memory, hemisphere and location (F(1,46) = 4.570, p = .038, η^2_p = .099) and between subsequent memory, time window and location (F(1.9, 88.6) = 8.831, p < .001, η^2_p = .159). Follow-up analyses from the first interaction looking at each quadrant individually showed an effect only for posterior-right (F(1,46) = 4.932, p = .031, η^2_p = .097), and not for the other three (p > .202). The second interaction was followed by looking at anterior and posterior sites separately. For both locations, a significant interaction between subsequent memory and time window was found (anterior: F(2.0,90.5) = 5.997, p = .004, η^2_p = .115; posterior: F(1.9,89.4) = 3.442, p = .038, η^2_p = .070). For anterior sites, subsequent memory was only significant in the first time window (F(1,46) = 6.812, p = .012, η^2_p = .129), and not for the others, p > .696. For posterior sites, the effect was only significant in the final time window (F(1,46) = 7.886, p = .007, η^2_p = .146), and not for the others, p > .182.

Because this is the first time that prestimulus Dm effects are analysed in OA, additional analyses were conducted within each age group to further explore the presence of that activity in each. This approach has been used in the literature (Angel et al., 2010; Berlingeri et al., 2013; Cansino, Hérnandez-Ramos, & Trejo-Morales, 2012; Cansino, Trejo-Morales, & Hernández-Ramos, 2010; James, Strunk, Arndt, & Duarte, 2016; J. Li et al., 2004). In YA, the statistical analyses showed that emotional valence did not interact with subsequent memory, p > .070. Significant interactions were found between memory, hemisphere and location (F(1,23) = 8.672, p = .007, η^2_p = .274) and between memory, location, and time window (F(2.0,45.5) = 3.400, p = .043, η^2_p = .129). Follow-up analyses from the first interaction looking at each quadrant individually showed a memory effect only for posterior-right (F(1,23) = 4.352, p = .048, η^2_p = .159), and not for the other three (p > .140). Follow-up analyses from the second interaction in each time window revealed a main effect of memory in the 200-800ms interval (F(1,23) = 4.369, p = .048, η^2_p = .160) and on the 800-1400ms interval (F(1,23) = 4.998, p = .036, η^2_p = .179), but not in the 1400-2000ms interval, p = .174. In none of the time windows, did memory interact with location, p > .085. In OA, the statistical analyses showed that emotional valence did not interact with subsequent memory, p > .080. Significant interactions were found between memory, location and time window (F(1.6,37.0) = 5.953, p = .009, η^2_p = .205), and between memory and time window (F(1.8,41.4) = 3.410, p = .047, η^2_p = .129). However, follow-up analyses for each time window revealed no further effects, p > .083. It seems clear that the results of the analyses incorporating both age groups were carried by the effects in YA, whereas the OA did not show statistically significant prestimulus Dm effects.

In summary, brain activity before images later given a remember judgment differed from activity elicited by images that were later forgotten. This difference took the form of more positive-going activity maximal on right-posterior sites. At first glance, the effect seemed to be general and independent of age or emotional valence, however, exploratory analyses looking at each age group revealed the effects to be present only for YA.

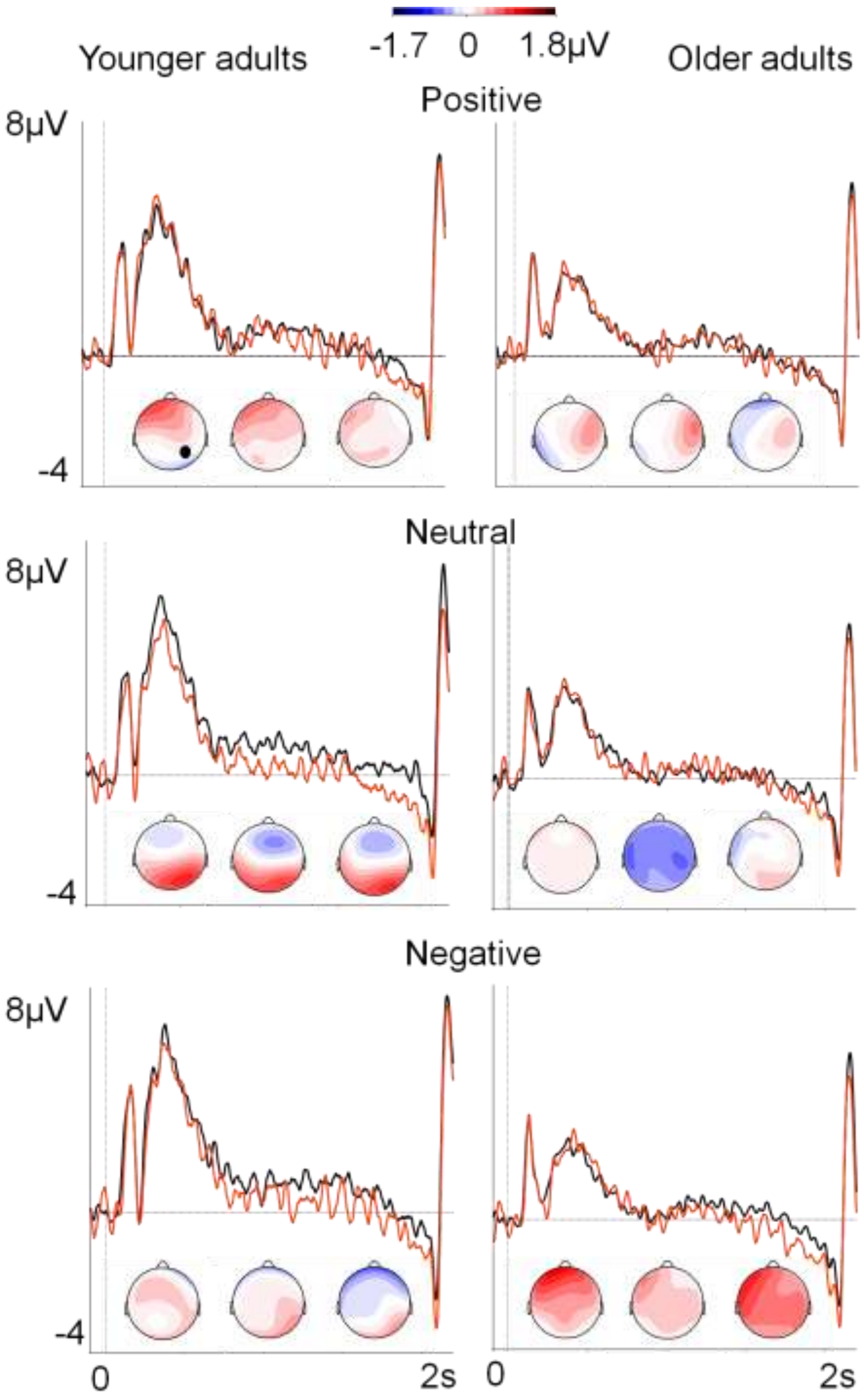

Figure 3.1.2. Subsequent memory effects before image presentation in younger and older adults.

Grand-averaged ERPs representing a right-posterior electrode (black dot). The voltage spline maps display the subtraction of the later forgotten trials (coloured lines) from the later remembered trials (black lines). These maps show the scalp distribution of the effects in the three time windows analysed: 200-800 (left), 800-1400 (middle), 1400-2000 (right). The dotted line represents cue onset.

Post-stimulus Dm effects

In YA (Figure 3.1.3), post-stimulus Dm effects for neutral images took the form of a sustained negativity on posterior sites that occurred during the entire epoch. Effects following positive images were positive-going and anteriorly distributed, beginning at around 300ms after image onset. Negative images elicited a left-frontal positive-going activity between 400 and 900ms after image onset. In OA (Figure 3.1.4), similarly to YA, Dm effects following neutral images took the form of a sustained negativity on posterior sites that occurred during the entire epoch. Effects after positive images were positive-going, anteriorly distributed and sustained in time. Activity following negative images was positive-going on right anterior sites but restricted in time to between 500 and 1200ms after image onset.

The same ANOVA factors used for prestimulus analyses were used here, with the exception of the chosen time windows (200-600ms, 600-1000ms, 1000-1400ms). Age did not interact with any of the other factors. Two interactions were significant that involved emotional valence: one between subsequent memory and valence ($F(2.0,90.7) = 4.152$, $p = .019$, $\eta^2_p = .084$); and the other between time window, subsequent memory, valence, hemisphere, and location ($F(3.5,162.7) = 2.597$, $p = .045$, $\eta^2_p = .053$). These interactions suggested that Dm effects were influenced by the valence of the image. Thus, each valence was analysed separately. Positive images revealed an interaction between memory and location ($F(1,46) = 12.512$, $p = .001$, $\eta^2_p = .214$), driven by a significant memory effect at anterior sites ($F(1,46) = 10.473$, $p = .002$, $\eta^2_p = .214$), but not on posterior sites ($p = .176$). This means that Dm effects for positive images were present during the entire epoch and maximal over anterior sites. Neutral images also showed an interaction between memory and location ($F(1,46) = 6.667$, $p = .013$, $\eta^2_p = .127$), driven by an effect at posterior sites ($F(1,46) = 11.404$, $p = .002$, $\eta^2_p = .199$), but not at anterior sites ($p = .176$). This indicates that Dm effects for neutral images were present during the entire epoch and maximal over posterior sites. Negative images showed an interaction between time window, subsequent memory, and location ($F(2,96) = 4.358$, $p = .016$, $\eta^2_p = .083$). This interaction indicates that Dm effects for negative images varied in time. Analysing each time window, only the 600-1000ms interval revealed significant effects, with an interaction between memory and location ($F(1,46) = 7.768$, $p = .008$, $\eta^2_p = .145$). This interaction was driven by a significant effect at anterior sites ($F(1,46) = 6.165$, $p = .017$, $\eta^2_p = .118$), but not at posterior sites, $p = .434$. This result suggests that Dm effects for negative images were maximal at anterior sites, but restricted in their time course to the middle time window.

In summary, age did not affect post-stimulus brain activity, but the emotional valence of the image did. Neutral items elicited a sustained negative-going activity at posterior sites, whereas emotional items elicited a positive-going activity at anterior sites (time-restricted for negative items, and long-lasting for positive items).

Old/new effects

Mid-frontal effect (Figure 3.1.5): Results showed a main effect of memory ($F(1,46) = 4.188$, $p = .047$, $\eta^2_p = .083$), with no effects of valence and age ($p = .858$). Because the mid-frontal effect has been shown to be preserved in ageing, within-group analyses were conducted to investigate the possibility that OA answered the memory task using familiarity. In YA, the mid-frontal effect was not present, ($p = .440$). In OA, the mid-frontal effect was present ($F(1,23) = 4.953$, $p = .036$, $\eta^2_p = .177$).

Left-parietal effect (Figure 3.1.6): YA showed a robust left-parietal effect. During the 500-800ms time window, OA showed a right-frontal effect, but seemed to not have a left-parietal effect at all. For the left-parietal effect, a main effect of memory ($F(1,46) = 21.317$, $p < .001$, $\eta^2_p = .317$) and an interaction between memory, age, and emotional valence ($F(1.9,87.4) = 3.302$, $p = .044$, $\eta^2_p = .067$) were found. Follow-up analyses for each age group and valence showed that the effect was present for YA (positive, $F(1,46) = 14.227$, $p = .001$, $\eta^2_p = .382$; negative, $F(1,46) = 30.606$, $p < .001$, $\eta^2_p = .571$; neutral, $F(1,46) = 18.479$, $p < .001$, $\eta^2_p = .446$) and not for OA (positive, $p = .496$; negative, $p = .189$; neutral, $p = .628$).

Right-frontal effect (Figure 3.1.7): YA and OA showed a robust right-frontal effect. The statistical analyses showed a main effect of memory ($F(1,46) = 37.551$, $p < .001$, $\eta^2_p = .449$), as well as its interaction with age group ($F(1,46) = 4.342$, $p = .043$, $\eta^2_p = .086$). Looking at each age group individually, the effect was found for both YA ($F(1,46) = 13.431$, $p = .001$, $\eta^2_p = .369$) and OA ($F(1,46) = 29.451$, $p <.001$ $\eta^2_p = .562$). An independent-samples t test did not show differences between the groups (means of 1.386µV for YA and of .963µV for OA, $t(34.290) = 1.112$, $p = .274$). Valence did not affect the right-frontal effect ($p > .057$).

In summary, the main between-group analyses revealed a weak mid-frontal effect and a stronger right-frontal effect, with no differences between the age groups. However, the left-parietal effect showed an interesting pattern, since YA displayed the effect for all three emotional valences, but OA showed a complete absence of the effect. Based on previous literature, a within-group analysis was conducted in the mid-frontal effect. This exploratory analysis suggested that OA used familiarity to answer the question, whereas YA used recollection.

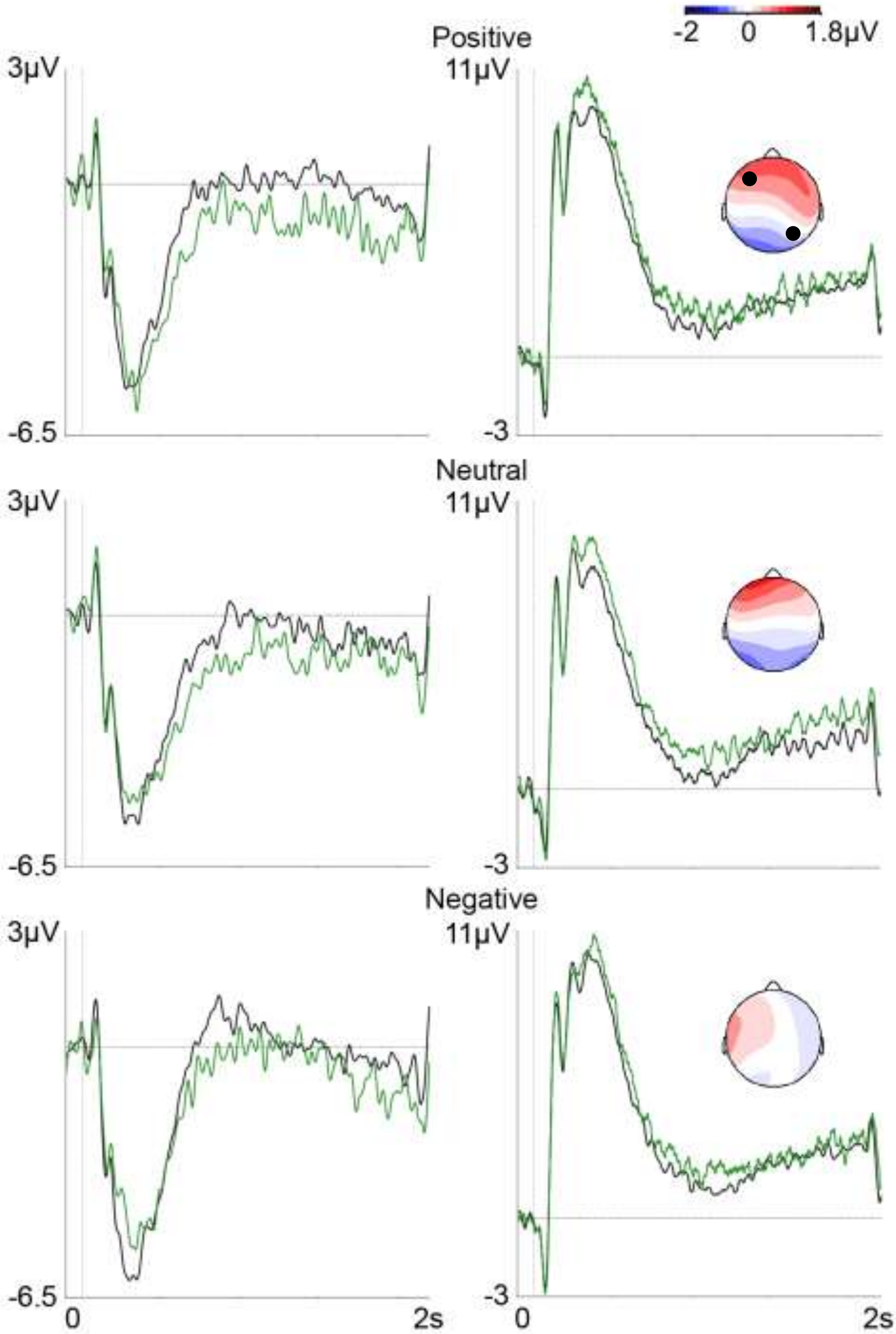

Figure 3.1.3. Subsequent memory effects following image presentation in younger adults.

The grand-averaged ERPs represent two electrodes (black dots): a left-anterior electrode (left) and a right-posterior electrode (right). The voltage spline maps display the subtraction of the later forgotten trials (coloured lines) from the later remembered trials (black lines). These maps show the scalp distribution of the effects in the 200-1400ms interval. The dotted line represents image onset.

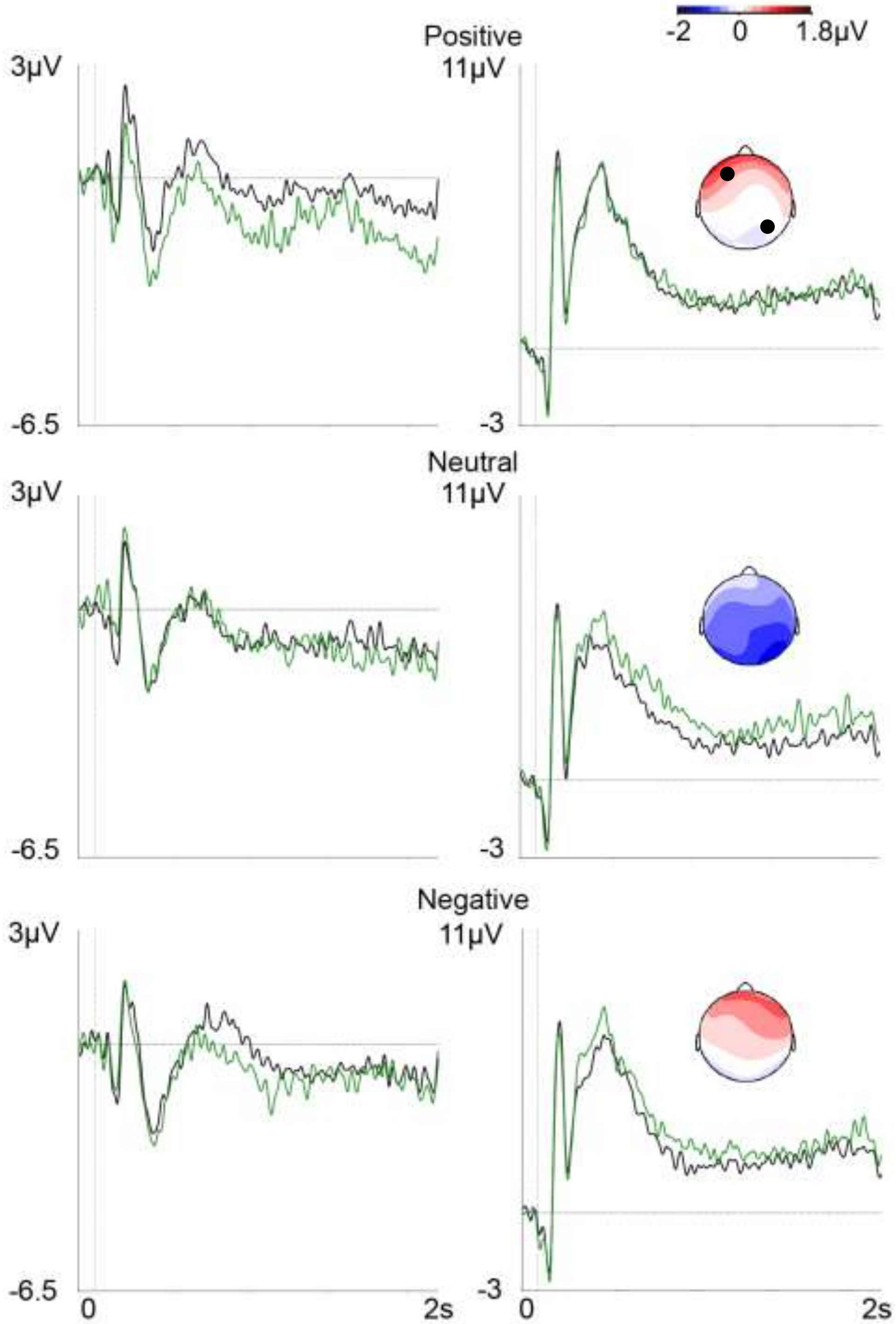

Figure 3.1.4. Subsequent memory effects following image presentation in older adults.

The grand-averaged ERPs represent two electrodes (black dots): a left-anterior electrode (left) and a right-posterior electrode (right). The voltage spline maps display the subtraction of the later forgotten trials (coloured lines) from the later remembered trials (black lines). These maps show the scalp distribution of the effects in the 200-1400ms interval. The dotted line represents image onset.

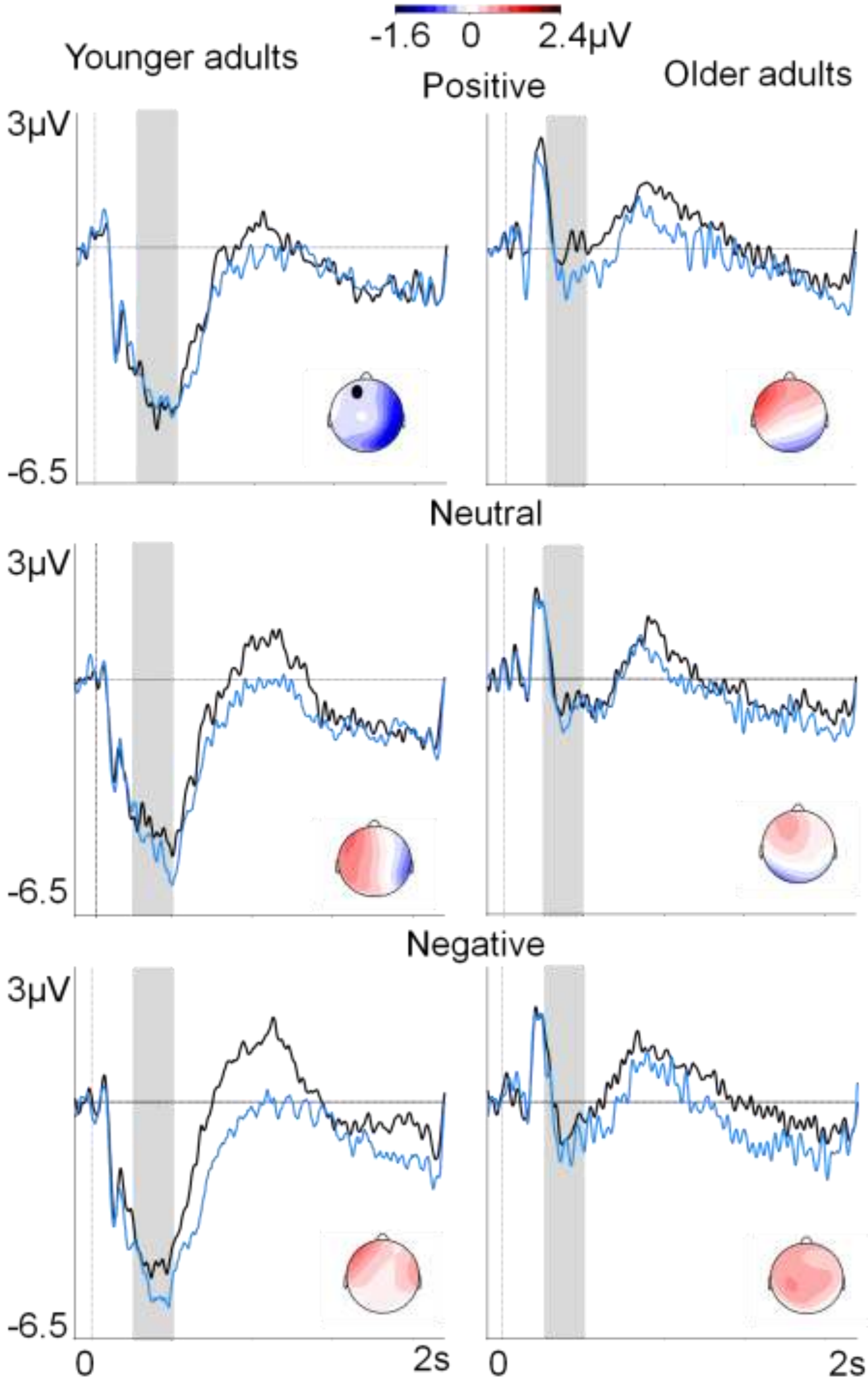

Figure 3.1.5. Mid frontal old/new effects in younger and older adults.
The grand-averaged ERPs show a mid-frontal electrode site (black dot). Scalpmaps display the subtraction of correct rejection trials (coloured lines) from remembered trials (black lines). These maps show the scalp distribution of the effects in the 300-500ms interval (grey rectangle). The dotted line represents image onset.

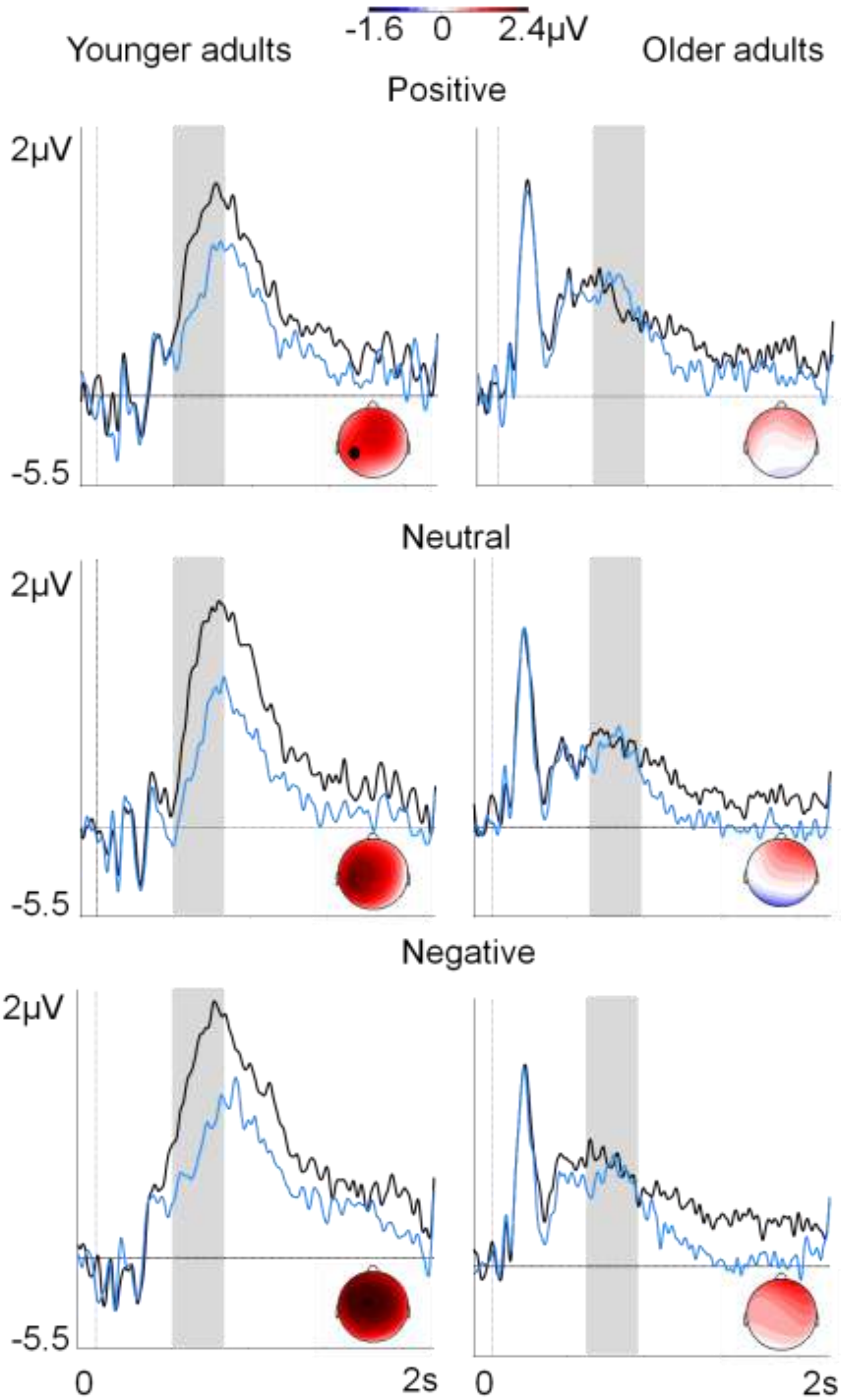

Figure 3.1.6. Left-parietal old/new effects in younger and older adults

The grand-averaged ERPs show a left-parietal electrode site (black dot). Scalpmaps display the subtraction of correct rejection trials (coloured lines) from remembered trials (black lines). These maps show the scalp distribution of the effects in the 500-800ms interval (grey rectangle). The dotted line represents image onset.

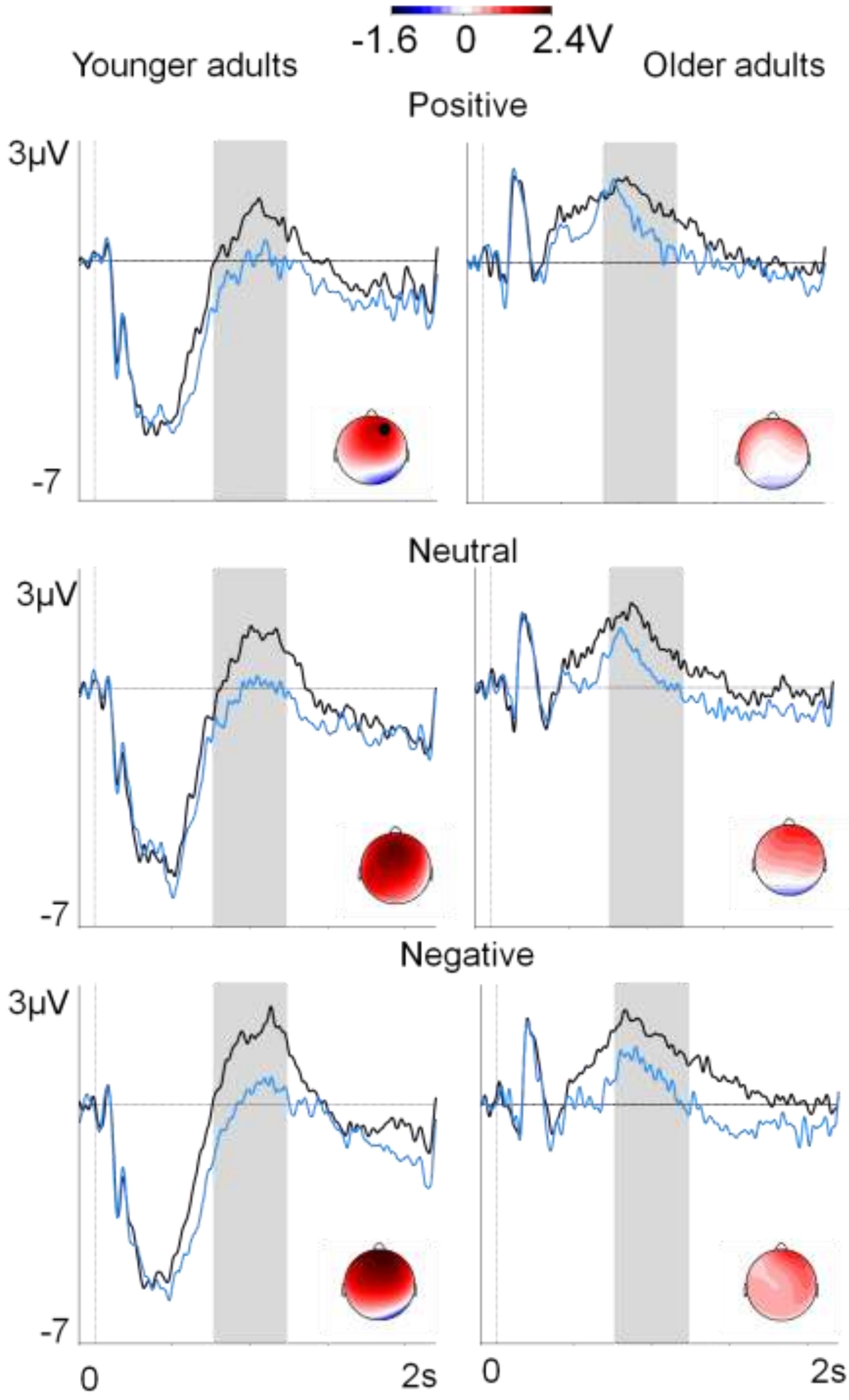

Figure 3.1.7. Right-frontal old/new effects in younger and older adults

The grand-averaged ERPs show a right-frontal electrode site (black dot). Scalpmaps display the subtraction of correct rejection trials (coloured lines) from remembered trials (black lines). These maps show the scalp distribution of the effects in the 800-1200ms interval (grey rectangle). The dotted line represents image onset.

Discussion

The aim of this study was to investigate possible interactions between ageing and emotion on encoding-related prestimulus brain activity. The results showed that prestimulus activity predicted later memory but was not modulated by ageing or emotion. Behaviourally, however, recollection differed for each age group based on the emotional valence of the image. Additionally, the current study revealed that emotion and ageing have separate effects, with the first influencing encoding, and the latter showing a strong influence on retrieval. Each of these findings will be discussed next.

Memory performance

Behaviourally, an interaction between emotion and age revealed that older participants had better discrimination for neutral than negative or positive images and younger adults remembered more negative than positive images. Although the better performance of younger adults with negative images is in line with the Negativity Bias (Baumeister et al., 2001), the results of the current study did not support the Positivity Effect (Carstensen & Mikels, 2005; Reed et al., 2014). The better performance of older adults with neutral images can possibly be explained by means of perceptual processing. The negative and positive pictures used in the present study could depict equally complex information (e.g. a happy party or a murder scene), it is possible that older adults only recalled the main object (central person or gun) and not the entire scene, making it more difficult to correctly recognize a picture in the test phase. On the other hand, most neutral images from the IAPS set depict single objects (Erk et al., 2003), which may have been more easily encoded by the older adults. A few findings in the literature support this view. Firstly, older adults have more difficulties in discriminating images with a high degree of ambiguity and complexity, possibly due to deficits in the perirhinal cortex (Ryan et al., 2012; Scheerer & Marrone, 2014). Secondly, older adults recall significantly fewer perceptual details from complex scenes than their younger counterparts (McDonough, Cervantes, Gray, & Gallo, 2014), especially if the scene has an emotional item. This happens because older adults are more likely to focus on the main emotional item in the image and to forget the rest of the elements (Waring, Addis, & Kensinger, 2013). A future study that balances the complexity of visual information in different groups of images, or that uses words as stimuli, would provide further support for this possibility. Although different perceptual features of the images may explain the behavioural findings of this study, it is noteworthy that many other studies also fail to find the Positivity Effect (Belham et al., 2013; Belham et al., 2017; Denburg et al., 2003; Fernandes et al., 2008; Fung et al., 2008; Gruhn et al., 2005; Newsome et al., 2012; Satler & Tomaz, 2011). This suggests that this effect may not be a universal phenomenon, but actually depend on experimental conditions (Carstensen & DeLiema, 2017; Denburg et al., 2003).

Despite the interactions with emotion, age did not have a main effect on memory, suggesting that the younger and older adults did not differ in their overall performance. The age groups also did not differ in their response bias, with both showing a bigger tendency to answer “old” to emotional than to neutral pictures (Gutchess, Ieuji, et al., 2007; Langeslag & Van Strien, 2008; Scheuplein, Bridger, & Mecklinger, 2014). The matched performance between the two age groups in the current study strengthens our ERP results. This is because, according to Werkle-Bergner, Muller, Li, and Lindenberger (2006), one of the reasons for the low number of studies investigating the Dm effect in older adults is the group differences in memory performance, which makes any comparison between ERP findings more difficult to interpret.

Prestimulus activity

In this study, prestimulus activity predicted later memory by taking the form of a positive-going activity stronger on right-posterior scalp sites across the entire cue-image interval. This pattern resembles the one found by Galli (2011; 2012) in polarity, scalp distribution and time course, and is thought to be related to emotional processing. According to the Socioemotional Selective Theory (Carstensen et al., 1999), ageing brings a shift in how one processes emotions, with younger adults focusing on negative events and older adults focusing on positive events. Thus, it was expected that younger adults would show prestimulus activity before negative images (cf. Galli et al., 2011) and older adults before positive images. The current study was the first to test prestimulus Dm effects in older adults and the findings suggest that ageing does not modulate anticipatory brain activity, which does not support the above-mentioned hypothesis. The non-modulation of ageing in preparatory activity has been found before. Bollinger et al. (2011)’s fMRI study with facial stimuli showed that the high-performing group of older adults had the same activation in the fusiform face area as younger adults during the anticipation period, whereas the poor performing older participants showed a reduction in activity in this brain area. In the current study, performance did not differ between age groups and neither did prestimulus Dm effects. Thus, a preserved anticipatory brain activity may have aided older adults to achieve a high performance in memory tasks. Future studies using the methodology employed here but with a larger number of older participants that can be separated into high- and low-performing ones may provide further clarity on this suggestion.

An exploratory analysis was conducted, despite the absence of interactions between age and valence, to confirm the presence of prestimulus Dm effects in older adults. This was done because the investigation of that effect in ageing is unprecedented. The analyses, however, confirmed the presence of anticipatory activity in younger adults, but not in older adults. A replication of the current study is, thus, fundamental to the better understanding of preparatory brain activity in ageing.

However, it is important to highlight that the younger group in the current study did not replicate the results found in Galli et al. (2011), since no effect of valence was found on prestimulus activity. This may have happened because of differences in the methodology between the two studies. Because the processing speed of older adults is usually slower than that of younger adults (Balota et al., 2000; Kerchner et al., 2012), the cues and images in the present experiment were left on the screen for a longer period of time. Galli et al. (2011) suggested that prestimulus activity only predicts later memory for negative pictures due to their evolutionary importance when compared to the other emotional valences. Negative stimuli would represent danger and threat, and anticipation would allow individuals to respond more prompt to these events. Following that premise, in the present study, the longer cue duration interval may have removed the biological urgency of negative events and given participants enough time to prepare equally for the three types of valences. Zanto et al. (2011) showed younger and older participants cues indicating the remaining time interval before the task started, which could be "short duration" or "long duration". For temporal cues indicating "short duration", younger adults used the information to prepare for the task, demonstrated by a faster reaction time and the presence of the contingent negative variation (CNV) brain activity, which reflects temporal expectation, attentional or motor preparation for an upcoming item (Macar & Vidal, 2004). However, when the cue indicated that a long time remained before the beginning of the task, neither age group used this information. Along the same lines, the longer duration time of the pictures in the current study may also have contributed to these results, since participants may have realized they would have enough time to make a decision after picture onset and that there was no need to prepare. Future studies should investigate if the discrepancy between the results of current study and those of Galli et al. (2011) was indeed due to different presentation times by adding a more demanding condition to the paradigm used here. In fact, that was the rationale behind experiment 3.2 of this thesis, described later in this chapter.

Encoding and retrieval

The current study showed that emotion only affected encoding, with emotional images eliciting a frontal positivity and neutral images a posterior negativity. The frontally-distributed positivity found for negative and positive pictures resembles the Dm effect typically seen in the literature (Paller & Wagner, 2002). Neutral pictures, on the other hand, elicited an unusual posteriorly-distributed negativity, which may mean that a different cognitive process was used for that valence. In the study by Dolcos and Cabeza (2002), participants intentionally memorized negative, positive and neutral IAPS pictures while rating their emotional valence. After each study block, a free recall test was conducted. In an earlier time window (600-900ms after picture onset), only emotional pictures elicited a subsequent memory effect, characterized by a positive-going activity on frontocentral areas. During this time window, topographic maps indicated that remembered neutral items elicited a more negative-going activity than forgotten neutral items, though the difference was not statistically significant. Similar to what was discussed for behavioural findings, the negative-going encoding activity for neutral images may have happened because of the very nature of those images on the IAPS set. Whereas negative and positive pictures are usually more complex scenes, neutral images are mostly composed of singular objects on plain backgrounds (Erk et al., 2003). Thus, encoding of neutral images may rely more on object-based perceptual processes than on deeper semantic processes associated with emotional information. This suggestion is supported by findings showing a posterior negativity in shallow study tasks (Otten & Rugg, 2001) and in visual imagery tasks (Gonsalves & Paller, 2000). In conclusion, it seems like Dm effects are qualitatively different between negative/positive and neutral information. Future studies should replicate our experiment using a more balanced set of stimuli, or perhaps words, to investigate if the posterior negativity was driven by the singularity of the objects in the images or to their actual neutral valence.

In the current study, the effects of ageing were only present during retrieval, and not during encoding. This suggests that the initial learning is similar between the age groups and only later retrieval is different for younger and older adults. This finding is in line with the one from Gutchess, Ieuji, et al. (2007), who studied encoding and retrieval of older adults in the same experiment, and against what one would expect from a literature review of individual studies (Friedman, 2003). The idea that ageing affects retrieval more than encoding is also in opposition to classic studies on the influence of divided attention during encoding and retrieval on memory performance, finding that accuracy is more severely affected, for both younger and older adults, when cognitive resources are diminished during encoding (Anderson, Craik, & Naveh-Benjamin, 1998; Glisky et al., 2001; D. C. Park, Smith, Dudley, & Lafronza, 1989). The common finding between the current study and that of Gutchess, Ieuji, et al. (2007) supports the importance of testing encoding and retrieval in one single study.

The present study revealed that only younger participants showed a left-parietal effect, thought to be an index of recollection, which would suggest that the typical recollection mechanisms are absent from the older participants. Most of the studies that reveal a smaller or absent left-parietal effect in older adults also reveal worse performance in this age group (Ally et al., 2008; Friedman, 2013; Prull et al., 2006; Wolk et al., 2009). This could indicate that the difference in retrieval-related brain activity is linked to a poorer memory. This was not the case in the present study, since performance did not differentiate between age groups.

It may be that older adults used a different brain mechanism to retrieve the images. For instance, Gutchess, Ieuji, et al. (2007) found that younger adults showed old/new effects in the three time windows that were analysed (300-500, 500-700, 700-900ms), whereas older adults only showed them for the last two time windows. Because both age groups had the same performance, the authors suggested that there may be a slower compensatory brain mechanism in older adults not detectable by the EEG technique (Gutchess et al., 2005). It is important to highlight that the analyses in Gutchess, Ieuji, et al. (2007) were done only with electrodes situated on the midline of the scalp, which means that they provide no information about the left-parietal effect. In the present study, the later old/new effect, measured on the right-frontal scalp regions, was equally present for younger and older adults, not supporting the idea that older adults used a delayed compensatory mechanism. It could be, however, that older adults used a qualitatively different mechanism as the one found by Friedman et al. (2010). These authors showed that, although older adults had a weaker left-parietal old/new effect than young adults, the ageing group showed greater negative-going activity on left fronto-central scalp sites in the 500-700ms interval after stimulus onset. This could mean that older adults use a different process for recognition memory, brought online when decisions cannot be based on conventional recollection processes (Duarte et al., 2006). In another study (J. Li et al., 2004), it was shown that when source memory performance is matched between young and older adults, the ageing group displays a strong left-sided negativity, whereas the younger group has the typical left-parietal effect. The stimuli used by Duarte et al. (2006), J. Li et al. (2004) and Friedman et al. (2010) were images of single objects, in contrast to the photographs of outdoor scenes used by Gutchess, Ieuji, et al. (2007). This may suggest that older participants prioritise a more perceptually-based retrieval strategy, whereas younger adults use a conceptually-based strategy, whenever possible. The results in the present study, however, did not reveal any retrieval-related negativity in the ageing group, which does not support the above-mentioned studies.

A last possibility is that older adults based their responses on familiarity rather than on recollection. Previous literature has shown this pattern. In a behavioural study, Bastin and Van der Linden (2003) tested recognition memory in younger and older participants using a yes-no task and a forced-choice task. Results showed that participants used recollection (Remember responses) to answer the yes-no task, and familiarity (Know responses) to answer the forced-choice task, although overall performance did not differ between the two conditions. The results also showed that older adults performed worse in the yes-no task and better in the forced-choice task, suggesting that ageing brings a decrease in the use of recollection but an increase in the use of familiarity to make memory decisions. A fMRI study (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006) reached similar results when testing younger and older adults in a confidence recognition memory task. Although accuracy did not differ between the two age groups, the results showed an age-related decline in the hippocampal activity connected to recollection, and an age-related increase in the rhinal cortex activity for familiarity responses. The authors conclude that older adults compensate for deficits in recollection mechanisms by using additional familiarity mechanisms. In the current study, although there was no statistical interaction between age and memory on the mid-frontal effect, analyses for each age group showed the effect to be present only in older adults. Although it is possible that this group did use familiarity-based retrieval during the memory task, this suggestion is not supported by the behavioural findings showing that older adults did not use familiarity more than younger adults. It would be valuable to investigate the ERPs related to know responses, which was not possible in the current study due to participants' high performance.

Conclusion

The findings of this study show that anticipatory brain activity during encoding predicts later memory without distinction between the age groups, eliciting a positive-going activity regardless of the emotional valence of the picture. The fact that, during retrieval, only younger adults displayed the typical left-parietal effect may suggest that older adults were applying a distinct but equally efficient mechanism for recollection. In contrast, post-stimulus brain activity was modulated by valence, since emotional images elicited a frontally-distributed positive-going activity, whereas neutral pictures led to a negative-going activity on posterior sites of the scalp. These results argue that an image's features only affect brain activity after they are encountered and that ageing has a much stronger influence during retrieval. In conclusion, the current study was the first to investigate younger and older adults' cortical activity in the three time points known to influence memory, and also the first to simultaneously analyse the influence of emotion on those effects. The findings suggest that only retrieval-related mechanisms are influenced by ageing and only encoding-related processes are influenced by emotion, although neither modulates prestimulus brain activity.

The next study was designed to address the differences in prestimulus activity between the current study and Galli et al. (2011) by manipulating stimulus duration during encoding. The next study also investigated how post-stimulus encoding activity and retrieval activity are influenced by deeper information processing during encoding.

Experiment 3.2: The effects of stimulus duration on encoding-related prestimulus activity for emotional images

The data for this experiment were in part collected by Stephanie Hatzifilalithis, a student on the UCL Cognitive Neuroscience MSc in the 2014/15 year, as part of her Master's research project.

Introduction

Memory for negative events has been found to be better than for neutral stimuli in tasks that test semantic (L. Levine & Bluck, 2010), episodic (Bisby & Burgess, 2014; Kensinger, 2008), and working (Roman et al., 2015) memory. Rozin and Royzman (2001) explain this pattern with the Negativity Bias hypothesis, which states that negative events are more salient, dominant and relevant than neutral ones, which increases their memorability. Galli et al. (2011) found that only negative images elicited anticipatory brain activity capable of predicting whether an item was going to be remembered or forgotten. As detailed in Chapter 1, the authors explained this finding based on an evolutionary account. Negative events are more likely to have a greater impact on the survival of an individual and, thus, their processing is a more urgent goal (Dolan, 2002). This explanation is supported by findings in the "face-in-the-crowd" paradigm, where negative faces in an array of distractors are identified more quickly than positive faces in the same context, both in the lab (Shasteen, Sasson, & Pinkham, 2014) and in more ecologically valid situations (Damjanovic, Pinkham, Clarke, & Phillips, 2014). Anticipating negative events for a more prompt or accurate response seems to be, therefore, adaptive (Galli et al., 2011).

In experiment 3.1, a Dm effect was found for prestimulus activity, but it did not differ as a function of emotional valence. The possibility was raised that the small methodological differences between that study and the one by Galli et al. (2011), necessitated by the inclusion of older adults, influenced anticipatory activity. In particular, the extended duration of the anticipation period (from 1.5s to 2s) and doubling of stimulus presentation time (from 1s to 2s) relative to Galli et al. (2011) may have removed the necessity of deploying preparatory mechanisms, since more time would be available to process the stimulus after its onset. If one knows there will be enough time to think and consider one's options before giving the response, would anticipation still play a role in memory encoding? Therefore, the investigation of how stimulus duration impacts prestimulus activity may improve the understanding of the functional role of such brain activity, similar to what has been done in the literature. For example, it is now known that anticipatory activity can be influenced by a number of factors, such as emotion regulation (Denny, Ochner, Weber, & Wager, 2013; Galli, Griffiths, et al., 2012), monetary reward (Gruber & Otten, 2010; Gruber et al., 2013), availability of cognitive resources (Galli et al., 2013), type of stimuli (Otten et al., 2010), type of encoding task (Padovani et al., 2011), as well as participants' gender (Galli et al., 2011) and curiosity (Gruber et al., 2014). In the current study, at least three outcomes are possible. First, prestimulus Dm effects may be found for negative items only regardless of their duration onscreen. This result would indicate that prestimulus activity is used in preparation for the processing of socially and biologically relevant information. Second, prestimulus Dm effects may be found for the short duration items only and regardless of their emotional valence. Such a result would suggest that prestimulus activity is used as an encoding aid when the time available for processing of the upcoming information is reduced. The third possible outcome is an interaction between the factors of emotional valence and stimulus duration. This would indicate that the relevance and urgency of the upcoming information are determinant on preparatory brain activity.

In the 1970s, Psychology studies suggested a positive correlation between the amount of processing of an item during encoding and the accuracy of its retrieval. For instance, Massaro (1970) claims that memory strength is enhanced if a stimulus is presented for a longer time during encoding. This would happen because a longer presentation allows the processing of more semantic features, which then, facilitates later memory performance. Similarly, Craik and Lockhart (1972) argue that memory is increases with longer study time, provided that a deeper analyses of the stimulus is conducted. However, despite the history of such findings relating stimulus duration during encoding and memory performance, very few studies have looked at how this relationship is influenced by emotion. One of them was conducted by Kensinger, Garoff-Eaton, and Schacter (2006), who investigated whether the increase in memory accuracy for negative items is influenced by how long the items were presented for. The authors found that items studied for a longer time were better remembered. Importantly, results also showed that, although negative images were on the whole better remembered than neutral items, the difference was larger in the long-duration encoding condition. This suggests that the increase in memory performance by the presence of emotionality is more pronounced if the stimuli are encountered for longer. The authors explained the findings by the fact that negative items usually attract more attentional resources (Shasteen et al., 2014) and, if more time is available, the attention will remain focused on the emotional item. On the other hand, if more time is given to the study of neutral items, participants will tend to get distracted by their own thoughts or other aspects of the testing room, giving emotional items a mnemonic advantage.

On a different note, it is known that the longer one is exposed to a negative stimulus, the less negative one will feel about it (Fanti, Vanman, Henrich, & Avraamides, 2009). This desensitization occurs even in people suffering from phobias (Watts, 1971). Bartholow, Bushman, and Sestir (2006) investigated the brain correlates of desensitization by measuring the P300 component to violent images (in a sequence of neutral images) in participants that used to play violent and non-violent video games. It was found that, in participants who were over-exposed to violent images, P300 was decreased, indicating that those violent images did not elicit surprise or novelty and did not require updates in working memory (Polich, 2007). These two lines of evidence seem to contrast with each other and the effects of duration on emotional memory are not fully understood.

The aim of the current study was to investigate if the amount of time available to view emotional items influences preparatory brain activity and later memorization. A similar methodology as the one used in experiment 3.1 was used here. Participants studied neutral and negative images in an incidental encoding task. Every image was preceded by a cue indicating the emotional valence and the presentation time (1000 or 2000ms) of the upcoming image. The study manipulated stimulus duration rather than the anticipation period (another difference between experiment 3.1 and Galli et al., 2011), because previous literature has already shown that encoding-related anticipatory activity is present with shorter and longer anticipation intervals (e.g. Otten et al., 2006). Twenty minutes after the end of the encoding task, participants were tested in a recognition memory task. EEG recordings were obtained during the entire session. As already mentioned, one of three possible outcomes for the ERP data was expected, in which anticipatory brain activity is modulated by the urgency of processing or by the biological relevance of the upcoming stimulus, or by an interaction of the two factors. In the latter possibility, prestimulus Dm effect is expected to be found only for negative items presented for short durations, and not for the other conditions. In terms of behaviour, it was predicted that longer duration times would generally lead to better memory (Craik & Lockhart, 1972; Massaro, 1970). Additionally, if longer study times increase the attention paid to negative images (Shasteen et al., 2014), a longer presentation time should induce better performance for negative images than a shorter time. However, if longer presentation desensitizes participants (Fanti et al., 2009), it was predicted that memory performance for negative images presented for a longer time would see no improvement or even lower performance.

Another aim of the current study was to evaluate how post-stimulus encoding and retrieval-related activity are influenced by stimulus duration during encoding. This is an important topic to improve comparisons between different pieces of research. For example, fMRI studies are conducted with long time intervals, whereas ERP studies have much quicker trials. Literature shows that depth of processing during encoding can influence later memory and also retrieval-related activity. For example, Rugg and colleagues (Rugg, Allan, & Birch, 2000; Rugg, Mark, et al., 1998; Rugg, Walla, et al., 1998) have done a series of experiments where stimuli are encoded in a shallow and in a deep condition. That can be, for instance, an alphabetical task and a semantic task. These studies show that the left-parietal effect is larger for deeply encoded items, whereas shallowly encoded stimuli show either a similar mid-frontal effect (Rugg, Mark, et al., 1998; Rugg, Walla, et al., 1998) or a stronger right-frontal effect (Rugg et al., 2000). Those findings suggest that items shallowly encoded are retrieved by means other than recollection and with lower levels of confidence, leading to extensive post-retrieval activity. An fMRI study (Otten, Henson, & Rugg, 2001) showed that post-stimulus Dm effect for deeply encoded words activate inferior prefrontal cortex and left hippocampus to a greater degree, whereas shallowly encoded words activated only a subset of these structures. Thus, it was predicted that the findings for the shallow conditions described above would be found for the short-duration images, and the findings for the deep conditions, for the long-duration images. In terms of valence effects, a frontally-distributed positive-going post-stimulus Dm effect was expected for negative items only, as previously seen in the literature (e.g. Dolcos & Cabeza, 2002; Yick et al., 2015) and in experiment 3.1 of this thesis. Also based on the literature, it could be expected that the left-parietal old/new effect (Langeslag & Van Strien, 2008) would be larger with negative items. However, experiment 3.1 suggested that emotions affect encoding but not retrieval-related activity, so no strong predictions were made.

Methods

Participants

Twenty-six female volunteers aged 19 to 25 years old took part in the study (mean 21.6, SD 2.16). Only females were tested to be consistent with experiment 3.1. Due to the emotional content of the stimuli used, after the initial interest in taking part, a sample of four images was sent to participants in order to confirm their consent for seeing that type of pictures. Participants had an average of 16 years of formal education. One participant was ambidextrous (not excluded from the analyses) and the others were right-handed. They were also tested for anxiety symptoms (Spielberger et al., 1970). Participants scored, on average, 36 (SD = 5.3) on the State questionnaire, and 39 (SD = 8.5) on the Trait questionnaire. For this study, only younger participants were recruited because the interest was in how stimulus duration affects prestimulus encoding-related and retrieval-related activity and how this is modulated by emotional valence. Since it is primarily younger adults who attend to and remember negative information better than other valences (Carstensen & DeLiema, 2017), the current study focused on that age group only. The investigation of the effects of stimulus duration on older adults' brain activity is also of interest and should be investigated in the future.

Materials

Stimuli were IAPS images. The official valence and arousal ratings of young women were used to select 341 negative images and 341 neutral images. Two images of each valence were used during recruitment only (see above), and another nine images of each valence were used during practice trials only. The remaining 330 images of each valence were divided into six sets of 55 each and used during study and test phases counterbalanced across participants. The mean valence and arousal values were respectively 2.66 (SD = .71) and 5.56 (SD = .79) for negative images, and 5.04 (SD = .53) and 3.98 (SD = .89) for neutral images. Both valence and arousal values differed between negative and neutral images (valence: $t(608.007) = -48.908$, $p < .001$; arousal: $t(649.688) = 23.854$, $p < .001$).

For the study phase, four sets of images were used to create the four experimental conditions, defined by the valence of an image and its presentation duration: (1) negative images presented for 1000ms, "negS", (2) negative images presented for 2000ms, "negL", (3) neutral images presented for 1000ms, "neuS", and (4) neutral images presented for 2000ms, "neuL". Valence was intermixed and duration was blocked, with half of participants starting with the long duration and the other half, with the short duration. More specifically, for half of the participants, negS and neuS images were mixed and presented in a randomized order in the first three blocks of the study task, whilst negL and neuL were mixed and presented in a randomized order in the final three blocks. For the other half of participants, the order was inverted. Participants were informed about the stimulus duration in each block with the words "short" and "long" presented on the centre of the screen. Each block lasted for approximately seven minutes and was separated from the next by one-to-two minute breaks.

For the test phase, in addition to the items used in the study phase, the remaining two sets of images were used as new items. These items were categorized according to their valence and presented for 1000s each: (1) negative images used as new items, “negN”, (2) neutral images used as new items, “neuN”. All images were intermixed and presented in a randomized order in eight blocks of approximately eight minutes each, separated from each other by one-to-two minute breaks. Stimulus duration was not manipulated during retrieval to isolate the effects of time-on-task and depth of processing during encoding on memory.

Procedure

Before the task began, participants were capped and connected to the EEG equipment. Exactly like experiment 3.1, the experimental session was divided into a study phase and a test phase. The study phase consisted of an incidental encoding task, in which participants were exposed to the images one at time and asked to make an indoor/outdoor judgement for each by pressing one of two buttons on a response box (Figure 3.2.1).

The duration of each trial was manipulated in a block-format. That is, at the beginning of each block, the words “long” or “short” were presented on the screen to inform participants of which condition they were about to receive. Within the blocks, each image was preceded by a cue that indicated the emotional valence. These cues were schematic sad and neutral faces, indicating, respectively, negative and neutral images (cf. experiment 3.1). Participants were asked to use their right thumb and little finger to give their judgements (response fingers were counterbalanced across participants). Between trials, a fixation cross was presented for a period of time that varied randomly between 2500 and 4000ms. This means that the total time for the long duration items was larger than for the short duration items. However, this was done so that the time in between trials did not systematically vary between conditions, which could lead to confounding spacing effects on memory (e.g. Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). The instructions for the study phase emphasized that participants should use the cues to prepare for the emotional valence and for the duration on screen of the upcoming image. The practice trials were conducted as experiment 3.1, in order to ensure participants had correctly understood the difference between remember and know responses.

After the end of study phase, there was a 20-minute break, when participants were allowed to rest and asked to complete the Anxiety Questionnaire. Also like experiment 3.1, the test phase consisted of a Remember/know recognition memory task (Tulving, 1985), chosen to allow a more thorough investigation of processes of recollection and familiarity. To keep the experimental parameters consistent across the study and test phases, each image was preceded by the same schematic facial cues used in the study phase to indicate its emotional valence. However, as already mentioned, there was no manipulation of the duration on screen for the test phase, i.e. the stimuli during the test phase were all presented for 1000ms. This value was chosen, rather than 2000ms, because this experiment followed up from experiment 3.1 and the study by Galli et al., 2011, and the parameters should be as similar to that study as possible, with only stimulus duration during encoding being manipulated. Between trials, a fixation cross was presented for a random interval between 1500 and 3000ms. Participants were asked to use their index, middle and ring fingers to indicate whether they "remembered" the image, "knew" the image, or if they thought the image was "new". Participants were instructed to respond before the next image showed up onscreen. Response fingers were counterbalanced across participants. At the end of the test phase, participants were asked to answer demographic questions (age, sex, first language, occupation, highest educational degree, and years of formal schooling) and debriefing questions that would inform about how they had approached the tasks. Participants were then taken to a second room so the cap could be removed and their hair could be washed. The total session time for this experiment, including EEG capping was of proximately 3 hours.

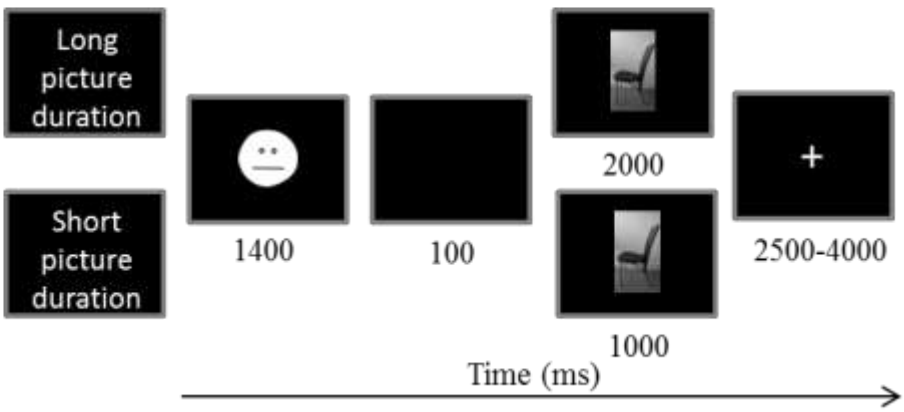

Figure 3.2.1. Trial sequence during the encoding phase.
Participants completed two blocks in the long condition and two in the short condition. In the first, images were presented for 2000ms, whereas in the second, they were presented for 1000ms. In all blocks, participants made indoor/outdoor judgments for each image. During the retrieval phase, all images were presented for 1000ms and participants judged if they were old or new using remember/know/new responses (see Figure 3.1.1).

EEG measures

Details for EEG acquisition and processing can be found in Chapter 2. ERPs were calculated for each participant and each electrode site according to the experimental condition and the recognition memory judgement given to each image. Thus, in the study phase, each EEG segment was classified as negS/negL/neuS/neuL and as remembered/known/missed. Segments were analysed separately for prestimulus activity (after cue onset) and post-stimulus activity (after picture onset) (Otten et al., 2006). Items presented only during the test phase were classified as negN/neuN and as remembered false alarm/know false alarm/correct rejection. Only post-stimulus activity was analysed for the test phase.

Eighteen participants were kept for the encoding analysis for having a minimum of 12 artefact-free trials in all conditions, whereas 19 were kept for retrieval analyses. The number of trials used in the ERP analyses can be seen in Table 3.2.1. Similar to experiment 3.1, “Know” judgments were not included in the analyses because insufficient numbers of trials were available to do so.

Table 3.2.1. Mean trial numbers used in the ERP analyses.

Encoding, prestimulus	NeuS	Remember Hits	43.7 (15.1)
		Misses	37.7 (13.9)
	NegS	Remember Hits	41.8 (16.4)
		Misses	36.6 (18.4)
	NeuL	Remember Hits	49.0 (16.8)
		Misses	34.1 (15.2)
	NegL	Remember Hits	45.2 (17.5)
		Misses	33.7 (16.9)
Encoding, post-stimulus	NeuS	Remember Hits	43.3 (15.2)
		Misses	37.9 (13.6)
	NegS	Remember Hits	41.9 (16.7)
		Misses	36.7 (18.4)
	NeuL	Remember Hits	48.7 (16.8)
		Correct Rejections	34.3 (15.4)
	NegL	Remember Hits	45.7 (17.7)
		Correct Rejections	33.1 (15.1)
Retrieval	NeuS	Remember Hits	36.8 (14.7)
	NegS	Remember Hits	36.5 (15.2)
	NeuL	Remember Hits	39.9 (17.0)
	NegL	Remember Hits	38.4 (16.5)
	Neutral	Correct Rejections	67.6 (26.7)
	Negative	Correct Rejections	60.1 (23.8)

The numbers in parentheses are standard deviations.

Behaviour and EEG analyses

Details for the behavioural measures can be found in Chapter 2. Pr and Br values related to remember judgments were computed separately for negS, negL, neuS and neuL images. Pr and Br values were submitted to a repeated-measures ANOVA with factors of emotional valence and duration on screen. ERP waveforms were contrasted according to the valence of the picture (negative/neutral), the duration on screen (short/long), the accuracy during the memory test (remember hits/misses for encoding data, and remember hits/correct rejections for retrieval data), and the interaction of these factors.

For the encoding data, the continuous ERP epoch was divided into three time windows in order to assess differences across time. Since only younger participants took part in the current study, the encoding time windows chosen followed Galli et al. (2011) and not the ones used in experiment 3.1. For prestimulus encoding-related activity, the chosen time windows were 300-700ms, 700-1100ms, and 1100-1500ms; for post-stimulus encoding-related activity, time windows were 200-600ms, 600-1100ms, and 1100-1900ms. Scalp electrodes were divided into the same four areas as used in experiment 3.1, with the same five electrodes in each in order to analyse frontal/posterior and left/right differences. ERP encoding data from the 20 selected electrode sites were submitted to a repeated-measures ANOVA with within-subjects factors of location (frontal/posterior), hemisphere (left/right), time window, subsequent memory (hits/misses), emotional valence (negative/neutral), and duration on screen (short/long).

For the retrieval data, the chosen time windows and scalp regions were the same as used in experiment 3.1, to capture the mid-frontal, left-parietal and right-frontal effects. Analysis of retrieval data was done specifically for each time window and scalp region and had only old/new status, emotional valence and duration on screen as factors for the ANOVA.

Results

Behavioural performance

To evaluate the indoor/outdoor responses (Table 3.2.1) given in the study phase, the data were submitted to an ANOVA with factors of valence (negative/neutral), and duration (short/long). Results showed that the proportion of indoor/outdoor responses was dependent on the valence of the image ($F(1,19) = 105.649$, $p < .001$, $\eta^2_p = .848$), with more indoor responses given to neutral than to negative images. Duration did not affect this measurement ($p > .236$).

Mean response time during study was also analysed to investigate how long participants took to make a decision in each of the four experimental conditions. Mean and standard deviation for each condition in milliseconds were: 774 (128) for negS, 921 (153) for negL, 771 (136) for neuS, 904 (.154) for neuL. Results revealed a main effect of duration (F(1,19) = 38.881, p < .001, η^2_p = .672), driven by a longer response time for long duration images than for short duration images. This result supports the manipulation chosen for the current study. In other words, participants understood that the images would be present for longer and took their time to make a decision. Valence did not influence response time (p > .056).

Table 3.2.2. Performance in terms of accuracy (%) and response time (ms) for the four experimental conditions during encoding.

	negS	negL	neuS	neuL
Judgment				
Indoor	37.6(11.1)	34.0(12.0)	53.8(8.5)	52.1(5.4)
Outdoor	61.8(11.0)	63.7(9.3)	46.4(8.6)	48.0(5.5)
Response time				
Indoor	805(142)	973(176)	776(135)	923(167)
Outdoor	742(121)	870(137)	765(143)	884(147)

negS = negative images presented for short duration; negL = negative images presented for longer duration; neuS = neutral images presented for short duration; neuL = neutral images presented for long duration. Numbers in parentheses are standard deviation. Data after exclusion of no-response trials.

Performance in the test phase was analysed based on the discrimination index Pr and the response bias Br in relation to remember responses. Table 3.2.2 shows the means and standard deviations for each measure in each of the four conditions. For Remember judgments, Pr showed a main effect of valence, being higher for neutral than for negative items (F(1,19) = 8.596, p = .009, η^2_p = .311), and a main effect of duration, being higher for long-duration than for short-duration items (F(1,19) = 8.183, p = .010, η^2_p = .301). However, no interaction occurred between the factors (p = .342).

Response bias Br for Remember judgments also showed main effects of valence and of duration. Specifically, participants had a stronger tendency to give “old” judgments to negative items than to neutral items (F(1,19) = 18.429, p < .001, η^2_p = .492) and to long-duration items than to short-duration items (F(1,19) = 8.302, p = .010, η^2_p = .304), but no interaction was found between the factors (p = .264).

In summary, participants showed better performance for neutral than for negative images and for long-duration than for short-duration images. In terms of response bias, participants were more liberal when answering negative items and long-duration items.

Table 3.2.3. Memory performance (%) for the four experimental conditions.

	negS	negL	neuS	neuL
Old items				
Remember	38.1(13.8)	4.8(14.8)	40.1(13.1)	43.2(15.4)
Know	27.0(13.0)	25.4(14.0)	22.3(11.4)	22.5(12.0)
Miss	34.4(15.0)	33.0(15.9)	37.8(12.8)	33.9(14.5)
New items				
Correct rejections	64.9(13.9)		73.9(12.4)	
False alarms	34.3(13.8)		25.4(12.3)	
Indices				
Pr rem	.24 (.16)	.27 (.17)	.31 (.15)	.34 (.16)
Br rem	.18 (.10)	.19 (.10)	.13 (.08)	.14 (.09)

negS = negative images presented for short duration; negL = negative images presented for longer duration; neuS = neutral images presented for short duration; neuL = neutral images presented for long duration. Numbers in parentheses are standard deviation. Pr = discrimination index for remember responses; Br = response bias for remember responses. Data after exclusion of no-response trials.

Prestimulus Dm effects

As can be seen in Figure 3.2.2, brain activity before images later given a remember judgment seemed to differ from activity elicited by images that were later forgotten in some of the conditions. In the negS condition, this difference took the form of posteriorly-distributed positivity that began early after cue onset and persisted until almost the end of the epoch. The same topography was visible for the negL condition, though here it looked smaller and more constrained in its time of occurrence. The neuS and neuL conditions also showed some positivity that was distributed on the scalp, but this activity seemed to be less consistent in time and also smaller than the one seen for the other two negative conditions.

As explained earlier, encoding prestimulus Dm effects were analysed in an ANOVA with time window, location, hemisphere, memory, emotion and duration as factors. The analyses revealed an interaction between emotion, duration, hemisphere and memory (F(1,17) = 6.763, p = .019, η^2_p = .284), and an interaction between memory and location (F(1,17) = 5.264, p = .035, η^2_p = .236). The first interaction was decomposed looking at each of the four experimental conditions, but no significant effects emerged (p > .165). The second interaction revealed a significant memory effect at posterior sites (F(1,17) = 9.824, p = .006, η^2_p = .366), but not at anterior sites (p > .432).

In Galli et al. (2011; 2012) and in experiment 3.1 of this thesis, the prestimulus effect for negative images was maximal on posterior areas. This also corresponds to the visual pattern seen in the current study. Thus, the set of analyses focused only on posterior sites. The ANOVA revealed an interaction between emotion, duration, memory and hemisphere (F(1,17) = 5.038, p = .039, η^2_p = .229), as well as a main effect of memory (F(1,17) = 9.824, p = .006, η^2_p = .366), but no main effect of emotion (p > .175). Because this experiment had specific predictions about the interactions between emotion and duration in prestimulus activity, each experimental condition was analysed individually. NegS showed a significant effect of memory (F(1,17) = 9.453, p = .007, η^2_p = .357), but the other three conditions did not (p > .076).

In summary, prestimulus Dm effects took the shape of positive-going activity on posterior sites, but only for the negative-short condition. Similar to experiment 3.1, the activity seemed to be larger for the right hemisphere, but that did not reach statistical significance.

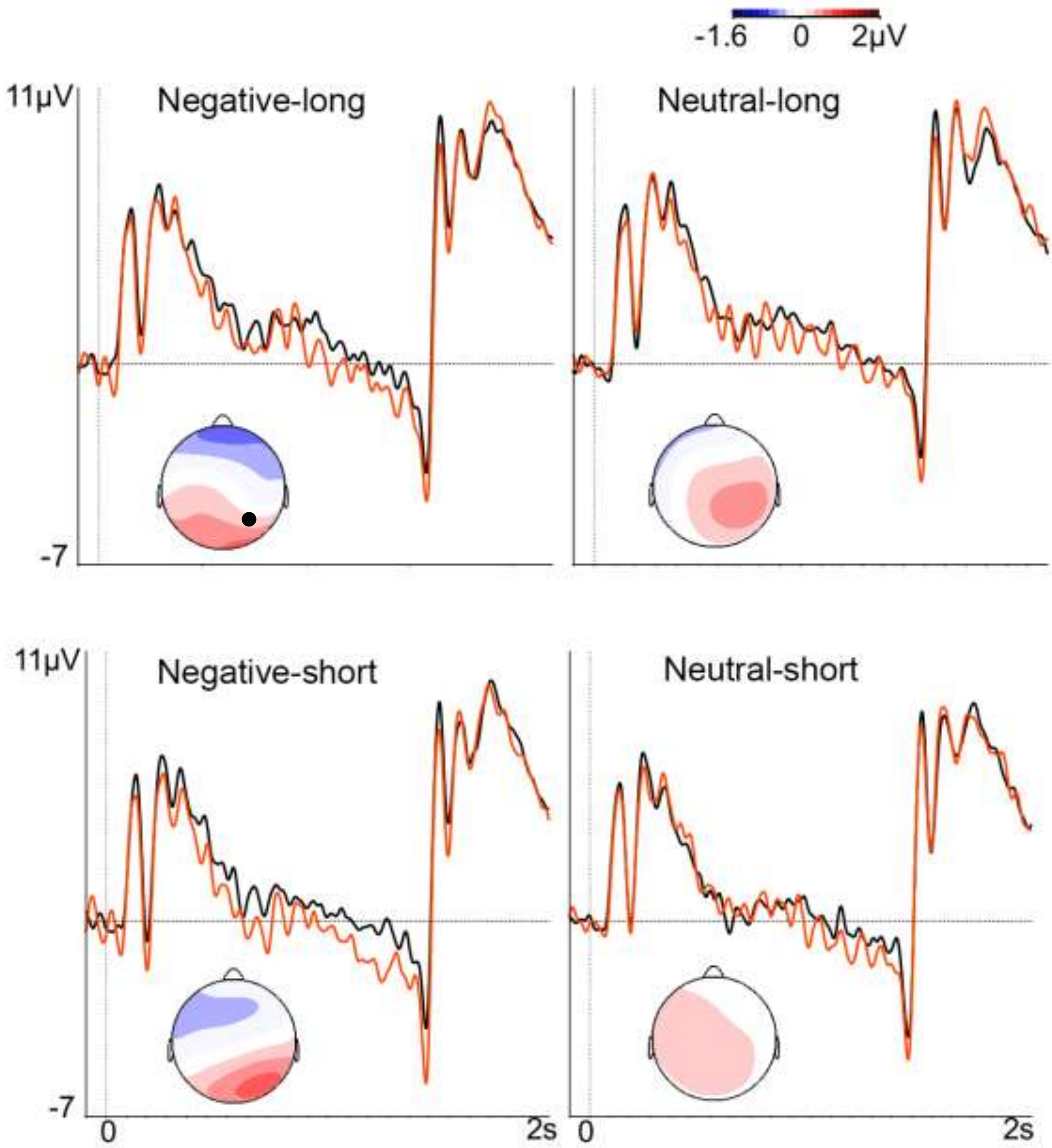

Figure 3.2.2. Subsequent memory effects before image presentation for the four experimental conditions.

The grand-averaged ERPs represent a right-posterior electrode site (black dot). The voltage spline maps display the subtraction of the later forgotten trials (coloured lines) from the later remembered trials (black lines). These maps show the scalp distribution of the effects in the effects in the 300-1500ms interval. The dotted line represents cue onset.

Post-stimulus Dm effects

Brain activity after image onset also seemed to differ between remembered and forgotten items, and it seemed to be influenced by the experimental manipulations, especially valence. The neuL condition showed a widespread negativity lasting the entire epoch. The other conditions showed a positive-going activity maximum on anterior sites, but stronger for negative than for neutral images (Figure 3.2.3).

To test the statistical significance of these effects, the same ANOVA factors as for prestimulus analyses were used here, with the exception of the chosen time windows (200-600ms, 600-1100ms, 1100-1900ms). This ANOVA showed an interaction between time window, duration, emotion, memory and hemisphere ($F(1.9,32.1) = 5.114$, $p = .013$, $\eta^2_p = .232$). The ANOVA also revealed an interaction between time window, duration, memory and location ($F(2.0,33.9) = 3.339$, $p = .048$, $\eta^2_p = .164$). Additionally, an interaction between time window and memory was found ($F(1.4,24.1) = 4.662$, $p = .030$, $\eta^2_p = .215$).

Unlike pre-stimulus activity, there were no specific predictions regarding the interaction between emotion and duration for post-stimulus activity. Thus, based on previous literature showing that encoding activity differs between negative and neutral images (e.g. Dolcos & Cabeza, 2002; Yick et al., 2015), follow-up ANOVAS were conducted for each emotional valence separately. Negative items showed an interaction between time window and memory ($F(1.5,25.8) = 5.750$, $p = .014$, $\eta^2_p = .253$). Looking at each time interval, only the second one showed a significant Dm effect ($F(1,17) = 6.073$, $p = .025$, $\eta^2_p = .263$). Neutral images showed an interaction between time window, duration, memory and hemisphere ($F(1.9,32.6) = 6.851$, $p = .004$, $\eta^2_p = .285$). A new analyses was done for each condition revealing a significant memory effect ($F(1,17) = 7.068$, $p = .017$, $\eta^2_p = .294$) for neuL, but not for neuS ($p = .269$).

In summary, emotion and duration influenced post-stimulus Dm effects. NegL and negS elicited a widespread positivity between 600 and 1100ms. NeuL showed a widespread negative-going activity, whereas no significant effects were found for the neuS.

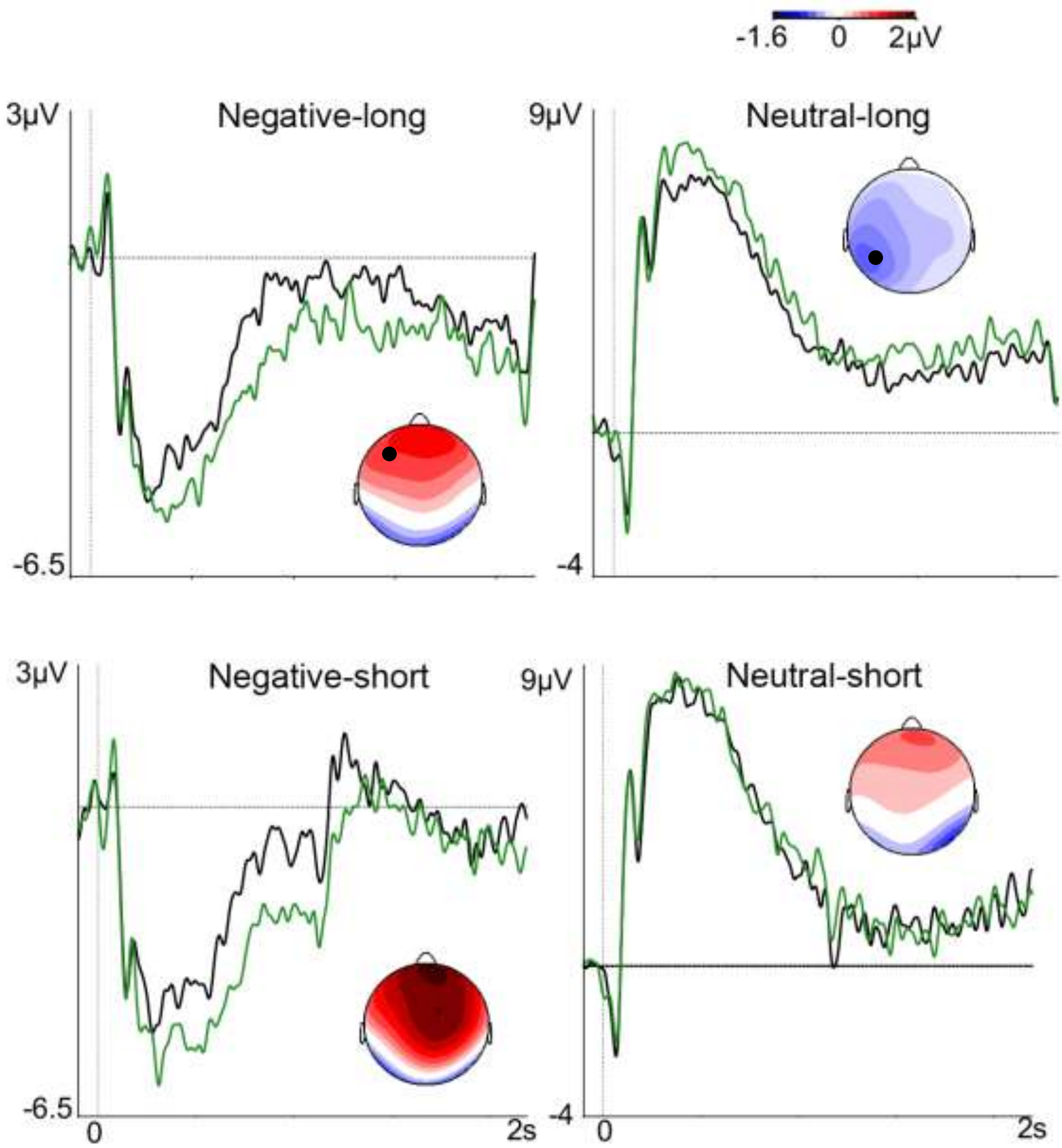

Figure 3.2.3. Subsequent memory effects following image presentation for the four experimental conditions.

The grand-averaged ERPs for the negative conditions represent a left-frontal electrode site, whereas the neutral conditions are represented by a left-posterior site (black dots). The voltage spline maps display the subtraction of the later forgotten trials (coloured lines) from the later remembered trials (black lines). These maps show the scalp distribution of the effects in the 600-1100ms interval. The dotted lines represent image onset.

Old/new effects

As explained in the methods section, the retrieval data were analysed according to established literature on the typical old/new effect regarding their spatial and temporal distribution. To test the statistical significance of the effects, three ANOVAs – one for each old/new effect – were conducted with factors of emotional valence (neutral/negative), duration of stimuli on screen (short/long) and memory (remember hits/correct rejections).

No mid-frontal effect was found (Figure 3.2.3, p = .194. For the left-parietal effect (Figure 3.2.4), the ANOVA revealed a main effect of memory (F(1,18) = 11.154, p = .004, η^2_p = .383), but no effects of valence or duration (p > .219). For the right-frontal effect (Figure 3.2.5), results showed a main effect of memory (F(1,18) = 8.171, p = .010, η^2_p = .312), an interaction between emotion and memory (F(1,18) = 6.813, p = .018, η^2_p = .274), and an interaction between emotion, duration and memory (F(1,18) = 7.424, p = .014, η^2_p = .292). Follow-up analyses for each condition revealed the right-frontal effect to be present for neuS (F(1,18) = 12.973, p = .002, η^2_p = .419) and negL (F(1,18) = 11.228, p = .004, η^2_p = .384), but not for the others (p > .120).

In summary, the analyses for the retrieval data revealed the absence of the mid-frontal effect, the presence of the left-parietal effect with no distinction between the conditions, and a larger right-frontal effect for the neutral short and negative long conditions.

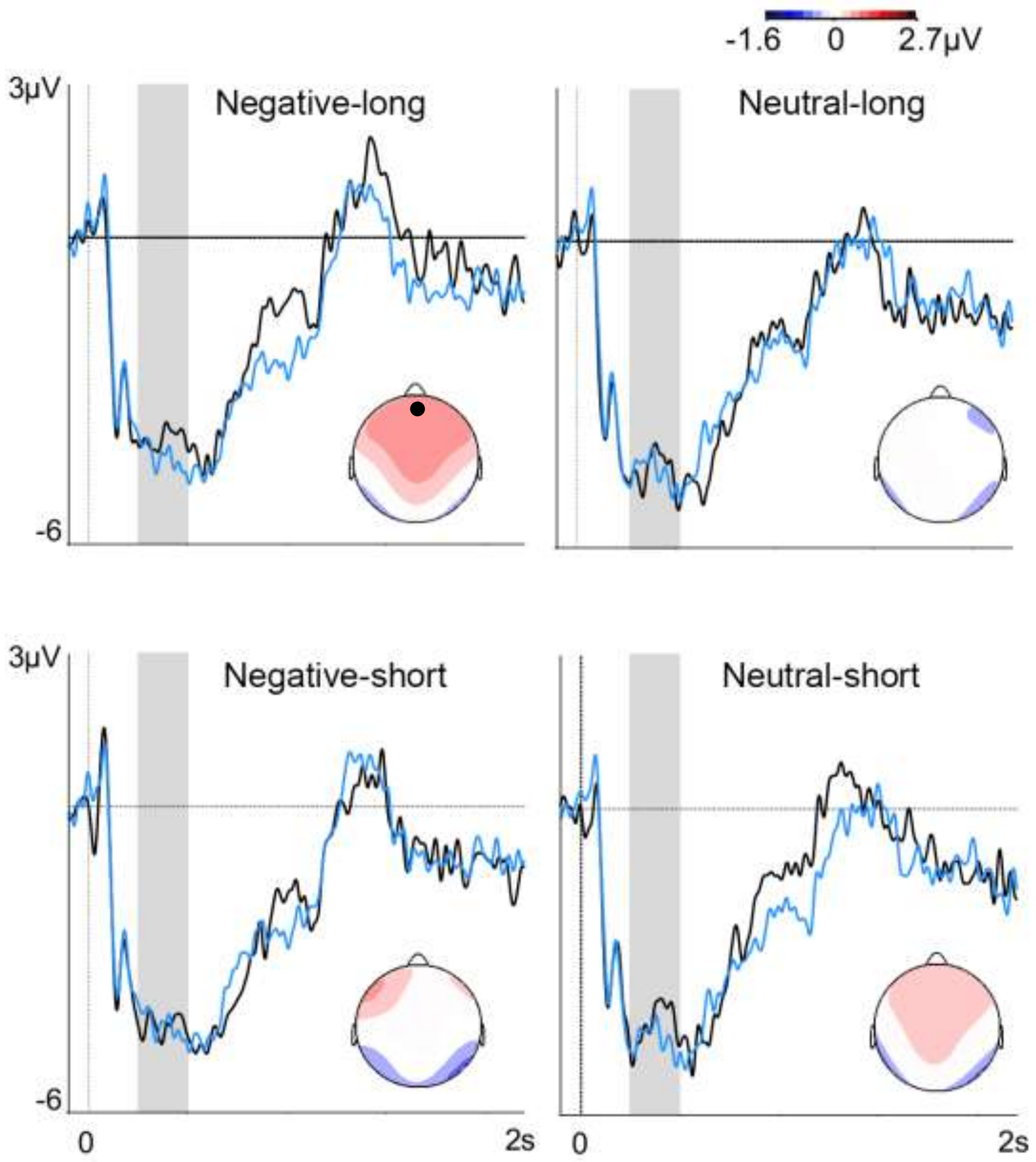

Figure 3.2.4. Mid-frontal old/new effects for the four experimental conditions.
The grand-averaged ERPs show a mid-frontal electrode site (black dot) to represent where the effect is maximal. Scalpmaps display the subtraction of correct rejection trials (coloured lines) from remembered trials (black lines). These maps show the scalp distribution of the effect in the 300-500ms time interval marked by the grey rectangle. The dotted lines represent image onset.

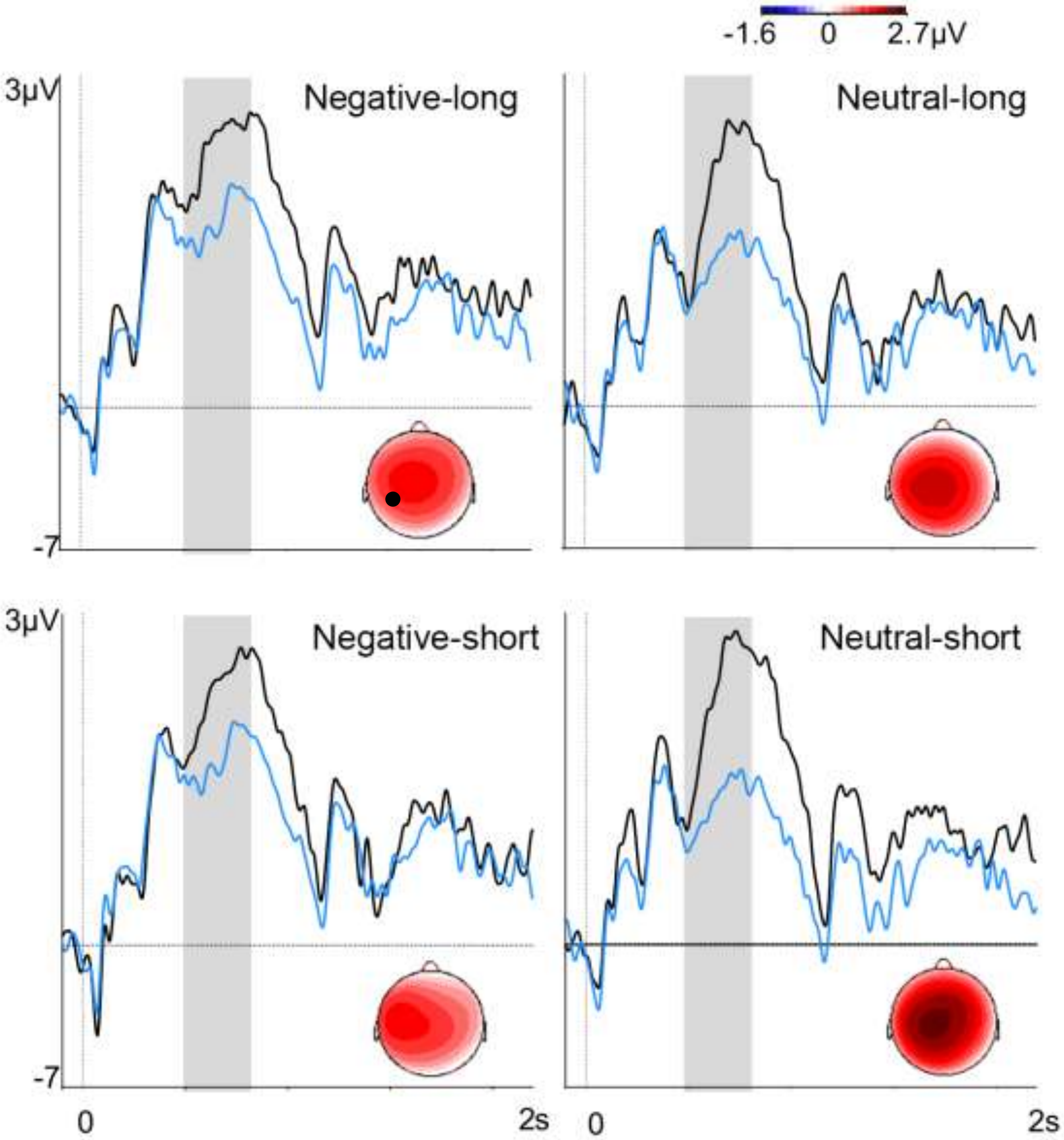

Figure 3.2.5. Left-parietal old/new effects for the four experimental conditions. The grand-averaged ERPs show a left-parietal electrode site (black dot) to represent where the effect is maximal. Scalpmaps display the subtraction of correct rejection trials (coloured lines) from remembered trials (black lines). These maps show the scalp distribution of the effect in the 500-800ms time interval marked by the grey rectangle. The dotted line represents image onset.

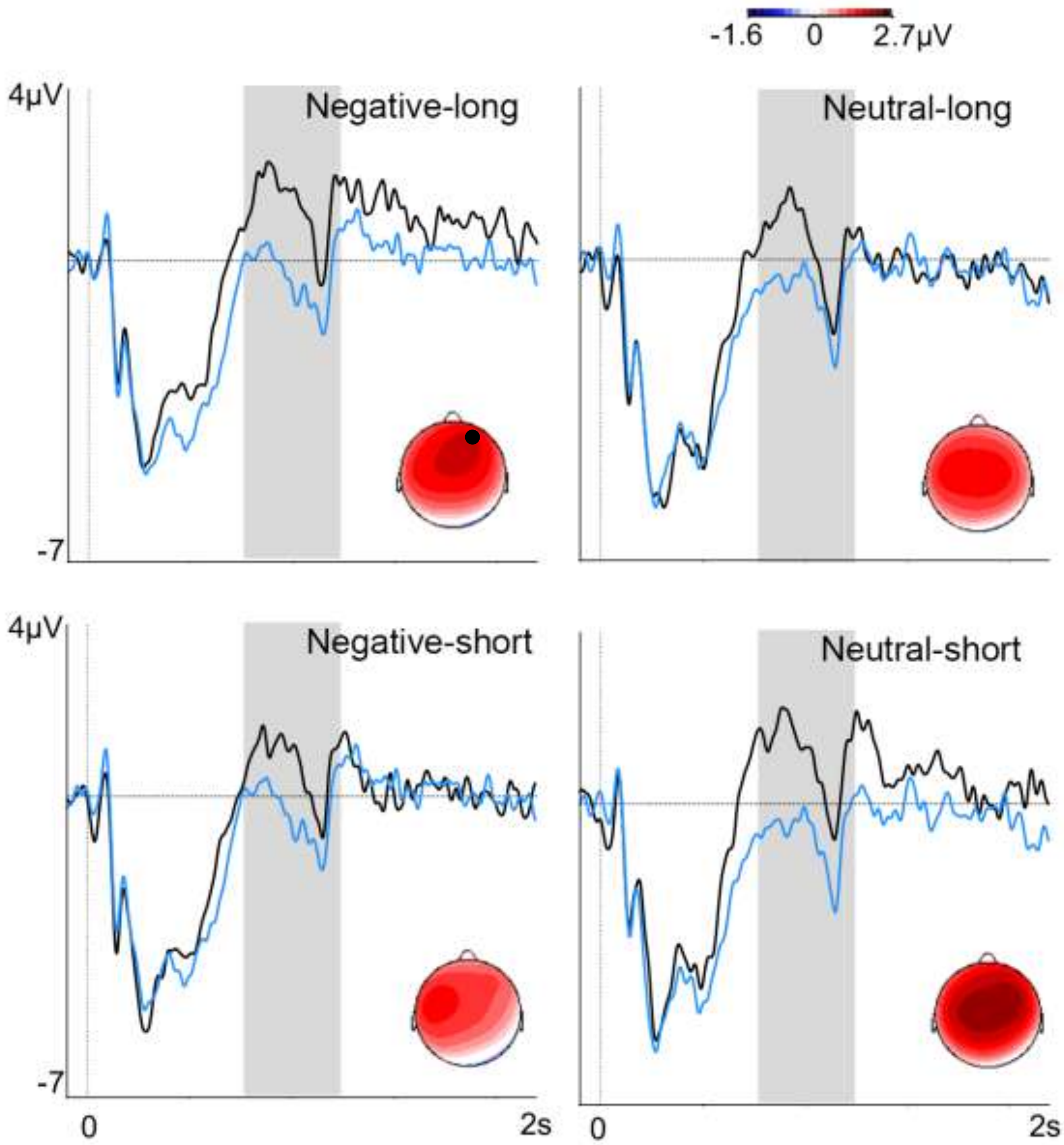

Figure 3.2.6. Right-frontal old/new effects for the four experimental conditions. The grand-averaged ERPs show a right-frontal electrode site (black dot) to represent where the effect is maximal. Scalpmaps display the subtraction of correct rejection trials (coloured lines) from remembered trials (black lines). These maps show the scalp distribution of the effect in the 800-1200ms time interval marked by the grey rectangle. The dotted line represents image onset.

Discussion

The current study investigated how manipulating stimulus presentation duration during encoding affects encoding-related and retrieval-related ERP activity. In line with one of the predictions, prestimulus encoding activity only occurred before negative images presented for a short duration. Behaviourally, both duration and emotional valence influenced memory performance but did not interact with each other. Post-stimulus encoding activity and retrieval activity were influenced by the interaction between duration and emotion, indicating that small methodological differences can have strong effects on brain activity. Each of these findings will be discussed next.

Memory performance

As mentioned in the introduction, not many memory studies have looked at the interaction between stimulus duration and emotional valence. The literature raises two hypotheses for how such as interaction would go. One says that negative images grab participants' attention, making them more memorable with a longer study time (Kensinger et al., 2006). Another hypothesis says that negative images become less emotional after some time, decreasing their mnemonic advantage over neutral items with a longer study time (Bartholow et al., 2006). The current results showed a main effect of duration (better performance for longer duration) and a main effect of emotional valence (better performance for neutral images), but no interaction between the factors. It can be argued that the presence of cues worked as a desensitizer and removed the impact usually caused by negative images, as shown by Grupe and Nitschke (2011). These authors presented participants with negative and neutral IAPS images preceded by one of three cues indicating the type of the upcoming picture – certainly negative, certainly neutral, and uncertain. The presence of cues significantly decreased the aversive impact of negative images, as measured by a mood questionnaire and by galvanic skin response. Thus, the presence of cues may have been responsible for the higher memory accuracy seen for neutral items in the current study. Although this idea seems interesting, it is also possible that, similar to experiment 3.1, the higher performance with neutral stimuli was simply caused by their lesser visual complexity.

The higher memory accuracy during retrieval and slower response time during encoding for long-duration images was an expected result. It replicates others showing that a longer study time usually improves later memory accuracy (Massaro, 1970; Memon, Hope, & Bull, 2003; Shapiro & Penrod, 1986) by possibly enriching the memory representation for that item (Craik & Lockhart, 1972). However, this explanation is challenged by the old/new effects found in the current study (discussed in more details later). If long duration items have a richer memory representation, it would be expected that they elicited a larger recollection-related old/new effect. However, the data show that the left-parietal effect was present with no distinction between the conditions. Nevertheless, more important to this thesis is that these results demonstrate that the experimental manipulation used in this study elicited behavioural differences. That is, it is clear that participants took longer to give a response when a longer decision time was available. Although it is impossible to know whether participants spent the extra second actively processing the stimuli or mind-wandering, the better performance with long-duration items suggests that those images were more deeply encoded than the short-duration ones.

Prestimulus activity

Encoding activity before stimulus onset predicted later memory in this study. It took the form of a positive-going activity on posterior sites and was present during the entire analysed epoch. This pattern resembles the one seen in experiment 3.1 of this thesis and in previous literature using emotional images as stimuli (Galli et al., 2011;2012). Also similar to prior studies is the finding that prestimulus Dm effects were only not significant for neutral images. In an fMRI study by Mackiewicz, Sarinopoulos, Cleven, and Nitschke (2006), participants saw a series of aversive and neutral images preceded by informative cues. Results showed that activity in dorsal amygdala and anterior hippocampus was related to anticipation of negative images and linked to later memory. Since the dorsal amygdala has been linked to threat detection and vigilance (Nitschke, Sarinopoulos, Mackiewicz, Schaefer, & Davidson, 2006), the authors conclude that anticipatory brain activity reflects the preparation for an upcoming aversive event by increasing perceptual attention and vigilance towards the approaching potential threat. Because neutral events do not usually represent imminent danger, anticipatory activity is not necessary before those images (Galli et al., 2011).

Of paramount relevance is the finding, in the current study, of interactive influence of duration and emotion on pre-stimulus activity. When each experimental condition was analysed separately, only preparation for the negative images presented for a short duration elicited a significant Dm effect. This result suggests that preparation for upcoming aversive events is no longer implemented when the available amount of time to make a decision is increased. When the time available for a decision to be made is expanded, no anticipatory brain activity is seen. One possible reason for that is that prestimulus activity is effortful and demands cognitive resources, as suggested by Galli et al. (2013). In that study, the authors used an encoding task similar to the one used in the present study, but they manipulated the amount of processing resources available for anticipation by asking participants to complete a concomitant task with different levels of difficulty. The results showed the presence of prestimulus Dm effect only when the parallel task was easy. The authors conclude that anticipatory activity is only present when enough cognitive resources are available to engage preparatory mechanisms. Although the scalp distribution of the activity found in that study (anteriorly-distributed negativity) was different from that seen here (posteriorly-distributed positivity), the findings of the current study support that idea. Instead of manipulating the amount of resources available, the present study manipulated the urgency of the next response, i.e. how long participants would have to make a decision. The fact that the prestimulus effect did not occur when the available time was long suggests that this brain activity is only deployed when necessary, possibly because it requires cognitive resources to be allocated.

The current study adds to the growing literature on the roles and characteristics of encoding-related prestimulus activity, however, several questions remain to be investigated. Firstly, it remains to be seen if the presence of anticipatory activity for short-duration images reflects a voluntary allocation of resources. Previous research has shown that prestimulus activity is under voluntary control by manipulating participants' will in memorizing certain stimuli over others (Gruber & Otten, 2010). It would be of interest to investigate the presence of prestimulus activity for long-duration items that are of greater interest to participants. That is, it would be interesting to study whether participants are able to deploy cognitive resources to anticipatory activity even when it is not necessary, but there is an incentive to do so. Secondly, experiment 3.1 of this thesis differed in its methodology from Galli et al. (2011) in anticipation period and stimulus duration. The current study manipulated only the latter because other studies have shown prestimulus Dm effects with different anticipation periods (Otten et al., 2006). However, a direct manipulation of anticipation period has not been done and it is unknown how this would affect prestimulus activity. Lastly, the current study focused on the differences between neutral and negative items, since that was the conflicting pattern seen between experiment 3.1 and Galli et al. (2011) and because the studied population was composed of younger adults. Thus, it is not clear how item exposure duration affects memory and brain activity for positive images or in older adults.

Encoding and retrieval

Post-stimulus Dm effects showed an interesting pattern. The effects were present for the negative images in the shape of a widespread positive-going activity that was not influenced by the duration of the image. In contrast, neutral images showed a negative-going Dm effect only present for the long duration. This inversion in polarity for neutral images is similar to the findings from experiment 3.1 in this thesis and may be related to those images eliciting a more perceptual Dm effect (Otten & Rugg, 2001). The lack of duration effects on negative images goes against the behavioural hypothesis of desensitization, which suggests that negative items exposed for a longer time become less aversive (Fanti et al., 2009) and may lose their mnemonic advantage over neutral items. This finding also offers support for the superiority of those events in attracting attention and efficient processing (Dolan, 2002). The presence of Dm effects for neutral images only when they were presented for longer duration suggests that, because these images are not as interesting or attention-grabbing (Vuilleurnier, 2005), they will only be strongly encoded if seen for a longer time.

During retrieval, a main left-parietal effect was found with no influence of duration or emotion. It was expected that long-duration images would elicit a stronger recollection-related activity if those items had been more deeply encoded (Rugg et al., 2000; Rugg, Mark, et al., 1998; Rugg, Walla, et al., 1998). This did not happen, since no influence of duration was found in the left-parietal effect. Similar to experiment 3.1, in which older adults showed good performance, but reduced left-parietal effect, in the current study, performance did not seem to show a correspondence with the recollection brain activity. It is possible that other brain mechanisms are acting instead of the left-parietal effect.

The right-frontal old/new effect was only present for negative-long and neutral-short conditions. As discussed in Chapter 1 of this thesis, the role of the right-frontal effect is debatable. Some authors suggest that it occurs when an upcoming decision is needed (e.g. Hayama et al. 2008), whereas others suggest that it is related to monitoring of the retrieved information, especially when that information is ambiguous or impoverished (e.g. Henson, Rugg, Shallice, & Dolan, 2000; Rugg et al., 2000). The results of the current study seem to agree with both hypotheses. The presence of the right-frontal effect for the neutral-short condition suggests compensation for the absence of Dm effects for this condition during encoding. That is, the images that did not receive strong support during encoding elicited a weaker retrieval, which was later compensated for with a larger post-retrieval monitoring. However, it is possible to speculate that the presence of the right-frontal effect for the negative-long images indicates that the abundance of encoded details of those images (Kensinger et al., 2006) allowed participants to make internal decisions. Therefore, the current experiment indicates that the right-frontal effect may have more than one functional role in episodic memory.

Conclusion

An important message from the current study is that methodological manipulations during one part of the memory process can have substantial impact on brain activity during the other moments. In the case presented here, the addition of 1000ms to stimulus presentation time during encoding influences not only encoding but also retrieval-related activity. This may help explain some of the mixed findings in the literature, such as the differences in prestimulus activity seen in Galli et al. (2011) and in experiment 3.1 of this thesis. Additionally, the current study supports the hypothesis that prestimulus activity is effortful and requires cognitive resources (Galli et al., 2013), only being used when necessary. The present study also showed that emotional valences are differently influenced by stimulus duration during encoding and that the right-frontal effect during retrieval may have more than one functional role.

Chapter 4: Voluntary emotion attribution and evaluative conditioning

Experiment 4.1: Voluntary emotion attribution by younger adults with different personality traits

The data for this experiment were in part collected by Amy Matthews, an A-level student in 2015, as part of her In2ScienceUK summer internship programme, and by a group of students on the UCL Psychology BSc in the 2015/16 year, as part of their second-year mini-project.

Introduction

Chapter 3 showed that the emotional valence of an image can influence memory performance and its brain correlates during encoding and retrieval. That chapter followed from an extensive literature on how emotional information is remembered by different populations. The next two chapters follow a line of studies that has not been so widely investigated. This line investigates emotions generated by participants, rather than presented through the experimental stimuli. Such emotion attribution may be seen as the other side of the coin of emotion regulation, the latter being known to affect memory performance (Dillon, Ritchey, Johnson, & LaBar, 2007; Richards & Gross, 2000) and to show age-related differences (Urry & Gross, 2010).

Emotion attribution is commonly studied via the evaluative conditioning (EC) paradigm. As explained in Chapter 1, EC is the change of valence of a stimulus due to its pairing with an emotional stimulus (Jones et al., 2010; Levey & Martin, 1975). This process has strong influences on one's decisions and attitudes (De Houwer, 2007). So, the next two chapters focus on how participants of different age groups and personality traits attribute positive emotions to neutral information and how that process relates to episodic memory in terms of behaviour and ERPs.

Before conducting experiments in which EC is manipulated, it is important to establish whether people have a natural tendency to attribute emotions to neutral information. That was the main aim of the current experiment. As mentioned, there is surprisingly little literature on emotion attribution. However, studies with clinical populations have shown that people who voluntarily deploy more positive reappraisal in their daily lives show higher well-being, higher social communication abilities, and fewer symptoms of depression (Ehring, Fischer, Schnulle, Bosterling, & Tuschen-Caffier, 2008; Gross & John, 2003; John & Gross, 2004). Thus, the study of how people naturally attribute emotions is important for the empirical study of EC and for the applied mental health literature.

Emotion regulation has not only been shown to be influenced by psychological and psychiatric conditions, but also by different personality traits. The literature shows that people differ in the mode and frequency with which they change the emotional status of an event (Egloff, Schmukle, Burns, & Schwerdtfeger, 2006; Volokhov & Demaree, 2010). For example, studies have found a negative correlation between positive reappraisal and neuroticism (Gross & John, 2003), negative correlations between positive reappraisal and depression and anxiety symptoms (Garnefski & Kraaij, 2006a, 2006b), positive correlations between positive reinterpretation and self-esteem and optimism (Carver, Scheier, & Weintraub, 1989), a positive correlation between fear conditioning and neuroticism (Hur, Iordan, Berenbaum, & Dolcos, 2016), and stronger affective priming effects in high-anxiety participants (Gibbons, 2009; W. Li, Zinbarg, Boehm, & Paller, 2008). Those studies suggest that individual differences are fundamental in the degree to which one changes the emotional status of an event. Accordingly, a second aim of the current study was to investigate if different personality traits would influence the amount or intensity of emotions attributed to neutral information.

In the current study, participants were given a list of neutral words and were simply asked to write short stories using the words as starting point. No further instructions, prestimulus cues or predefined options were given. The aim of the study was to test whether participants would show a natural tendency to attribute emotions – either negative or positive – to neutral information. The stories were rated by a second independent group of participants in terms of valence and arousal. These ratings were later correlated with the personality traits of the two groups of participants.

Methods

This study was conducted with two sets of participant recruitments, one year apart from each other. Independent sample t tests were conducted to compare the participants from the two recruitment periods. No statistical differences in personality traits ($p > .073$), valence ratings ($p > .842$), or arousal ratings ($p > .849$) were found, so participants from the two recruitments were combined for the data analyses.

Table 4.1.1. Mean scores on the personality traits for the group of writers and readers.

	Writers	Readers
Openness	3.57 (0.54)	3.64 (0.65)
Conscientiousness	3.55 (0.68)	3.43 (0.80)
Extraversion	3.29 (0.77)	3.29 (0.64)
Agreeableness	3.69 (0.59)	3.62 (0.64)
Neuroticism	2.73 (0.74)	3.01 (0.90)

Numbers in parentheses are standard deviations.

Participants

41 participants took part in the first recruitment period and 76 in the second one. Thus, in total, 117 participants took part in this study (83 females, mean age = 24.85 ± 10.07 years). The first half of participants to sign up to the experiment in each recruitment period was allocated to the writers group, and the second half, to the readers group (Table 4.1.1). So, in total, 57 participants were writers and 60 were readers. The Big Five Inventory (John et al., 1991; John et al., 2008) was administered to assess their personality traits at the end of the session. The writers` task was to create short stories with the neutral words given. The readers` task was to rate those paragraphs according to their emotionality.

Stimuli and procedure

This experiment was conducted using the software Gorilla.sc (www.gorilla.sc/about) for its simplicity of use.

Writers: A list of 32 nouns (mean valence = 5.10, mean arousal = 3.71), selected according to the criteria delineated in Chapter 2, were presented one at a time to each writer on a monitor. The order of the words was fixed. Participants were given 40 minutes to write short stories using each word presented. The task was self-paced, that is, each word remained onscreen until participants completed the current story and moved forward to the next word. Because this study was interested in obtaining the most natural responses from participants, there were only two rules for the stories. The first rule was that the stories' length should be between two and five lines, and the second rule was that they should contain the word given. Other than that, participants were free to decide how to use each word, e.g. as the main object of the plot, simply as the first word of the story, etc. The stories should be typed on the computer keyboard.

At the end of the 40 minutes, participants were requested to finish their current story and then stop.

Readers: Firstly, the stories that did not conform to the rules, were unintelligible or contained swear words were excluded from the dataset (approximately 25%). Next, the 975 remaining stories were randomised and divided into sets of 55 or 56. This was done so that the experimental session was not too long for the readers, and also so that the each story would be rated by at least three readers. The readers were not informed that the stories had been written by another group of participants. The readers were asked to rate each story according to its valence ("how unpleasant (negative) or pleasant (positive) is this story?") and arousal ("how arousing, alerting or exciting is this story?") on a 1-9 scale. The readers were also given 40 minutes to complete the task. The task was self-paced, so the stories remained onscreen until participants had rated them and moved forward to the next one. The ratings were given by moving a virtual scale with the computer mouse.

Data analyses

The written stories were averaged in terms of emotional valence and arousal for each writer and for the group. Valence ratings of less than 4 were considered negative, ratings of between 4 and 6 were considered neutral, and ratings above 6 were considered positive (Lang et al., 1997; Warriner et al., 2013). Values were compared with the official ratings for the words obtained from Warriner et al. (2013) via one-sample t test, and correlated with the personality scores obtained via the questionnaire.

Results

The average valence rating of the stories was 4.69 (.59), ranging between 2.23 and 5.88. The average arousal rating was 4.33 (.76), ranging between 2.90 and 6.10. As can be seen in Figure 4.1.1, these values correspond to neutral valence (grey area) and mild arousal. The one-sample t tests revealed that the story valence ratings were significantly more negative (less positive) than the official word ratings ($t_{(56)} = -5.283$, $p < .001$). The tests also revealed that the stories were more arousing than the official arousal ratings of the words ($t_{(56)} = 6.132$, $p < .001$).

Personality traits

Correlations between the five personality traits of the writers and the two emotionality measurements of the stories revealed the following significant results: Conscientiousness X Valence, r = .325, p = .014; Agreeableness X Valence, r = .283, p = .033; Neuroticism X Valence, r = -.382, p = .003. After applying Holm`s correction for multiple tests (Baumard et al., 2016; Holm, 1979), only the correlation between Neuroticism and Valence survived significance (p = .030, Figure 4.1.2).

Personality scores for the readers were also correlated with the two emotionality measurements, however no significant correlation was found (p > .064).

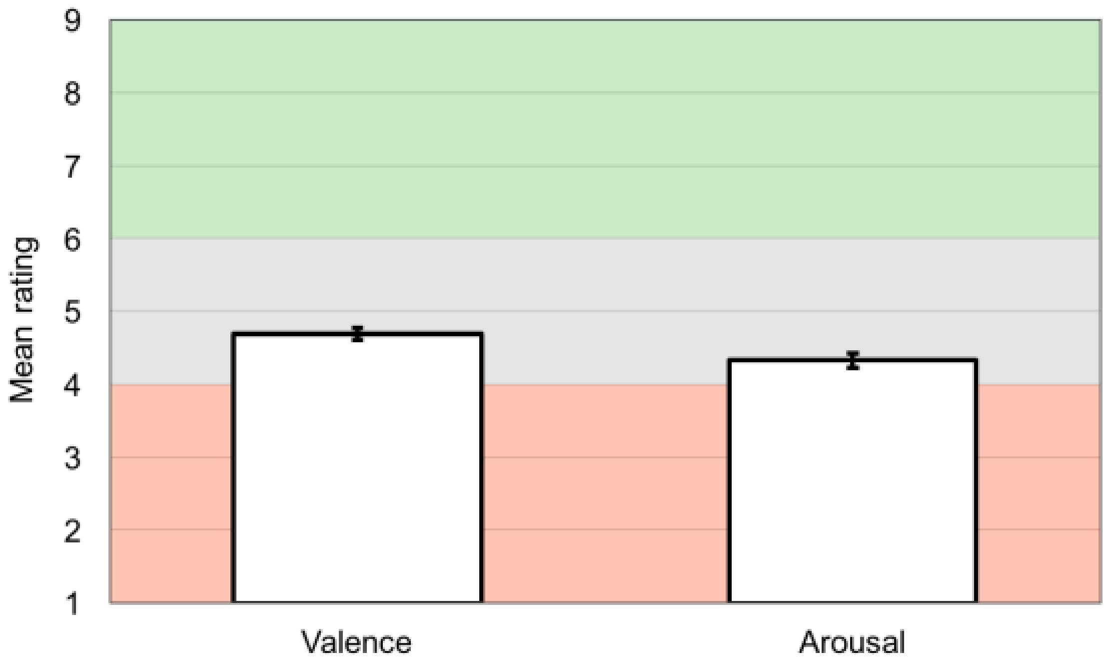

Figure 4.1.1: Mean valence and arousal ratings.

Mean ratings given by participants in the readers group to the stories written by participants in the writers group. Bars represent SE. The colours in the background represent negative (red), neutral (grey) and positive (green) values of valence.

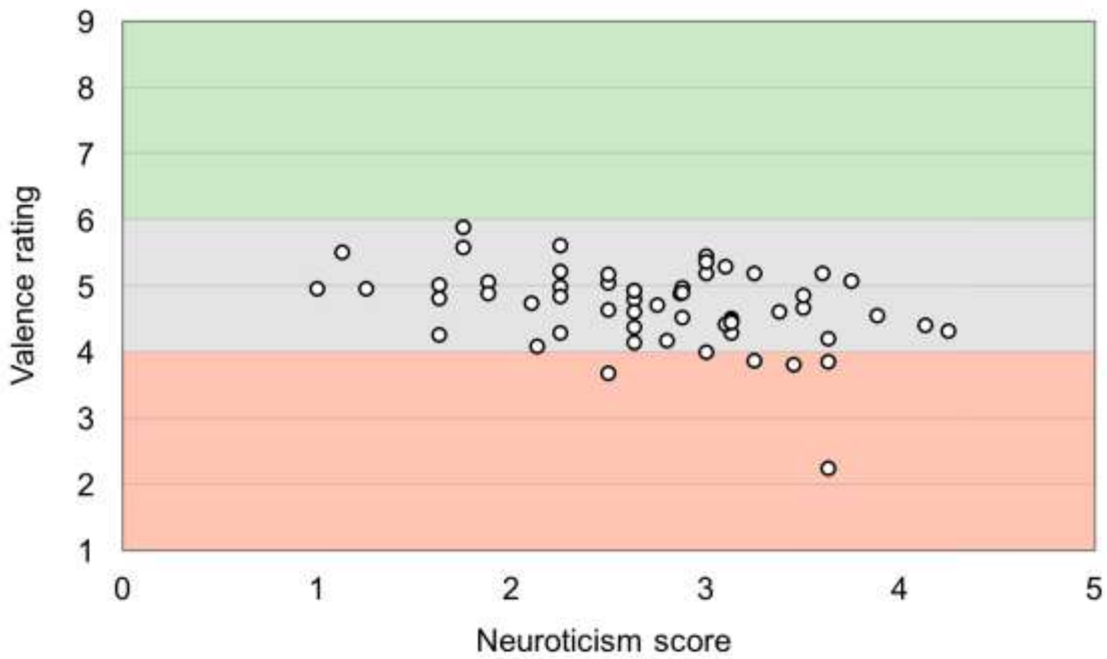

Figure 4.1.2. Correlation between neuroticism scores and valence ratings. Participants that scored higher in the neuroticism scale also rated wrote stories that were more negative. The colours in the background represent negative (red), neutral (grey) and positive (green) values of valence.

Discussion

The aim of the current study was to test whether there is a natural tendency to add emotionally to neutral stimuli, and how this is affected by different personality traits. To that end, one group of participants wrote short stories using neutral words, and a second group rated those stories on emotional dimensions. Results showed that, on average, although the stories were still within the neutral range of valence, they were more negative than the official ratings of the words taken from the original database. Similarly, the stories were rated as more arousing than the official arousal ratings of the words. Interestingly, a correlation between emotional valence and neuroticism emerged, with people with higher scores of neuroticism writing more negative stories.

Research about down-regulation of negative emotions is very common, whereas studies about the increase of positive emotions only took off in the past two decades (Tugade & Fredrickson, 2007). Surprisingly, research about the addition of emotionality to neutral information is rarely found in the literature. When neutral items are used, they are commonly only a baseline. For instance, S. H. Kim and Hamann (2007) measured participants` brain activity when they increased and decreased emotions felt from positive and negative images, though neutral images were only used in the “watch” condition and thus no data were obtained on how emotionality for this type of item is regulated. The current study tried to fill this gap in knowledge and the results indicate that people seem to slightly add negativity to neutral words, although not enough to change the category of the words from neutral to negative. As mentioned in the introduction of the current experiment, previous literature has found that clinical populations, such as people with anxiety and depression, tend to use less positive reappraisal strategies than controls (Garnefski & Kraaij, 2006a, 2006b). Similarly, participants with those clinical traits tend to interpret some types of ambiguous information as more negative than healthy participants (Eysenck, Mogg, May, Richards, & Mathews, 1991; Mogg, Bradbury, & Bradley, 2006).

It is noteworthy that in Eysenck, et al. (1991) and in Mogg et al. (2006), a main effect of valence was found together with an interaction between group and valence. That is, participants in general assumed the negative meaning of ambiguous information more often than the neutral meaning. Thus, although the effects were significantly larger for the clinical population, healthy participants also showed a tendency of inferring negative emotion from ambiguous information. In the current study, the data suggest that healthy participants not only interpret ambiguous information as negative, but they also add negative emotion to neutral words. It is important to mention that participants in the current study reported not having suffered from psychological or psychiatric conditions, but no anxiety or depression questionnaires were administered to have an objective measure. Thus, an interesting future study would be to replicate the current methodology with clinical populations so their emotion attribution could be compared with controls.

Alternatively, it is possible that the difference in valence between the written stories and the official word ratings were caused by cultural factors. That is, the words’ valence ratings (Warriner et al., 2013) were obtained from a population in the United States of America, whereas the current participants were residents in the United Kingdom. Similarly, the original ratings were obtained in an online study, whereas the current experiment was conducted in the lab with the presence of a researcher. Although it is unclear how those factors may have influenced the results, it would be interesting to ask a group of UK participants to rate the words used in the current study. Moreover, the lower valence and higher arousal of the stories in comparison with the words may also have been caused by the complexity of the sentences, as has been shown for IAPS images (Ochsner, 2000).

Previous research has shown that people that are under constant stress from dealing with negative situations, such as a chronically ill relative, learn to think of ordinary events as positive (Folkman & Moskowitz, 2000). This suggests that people may have the potential to add emotionality to neutral information when given the necessary conditions. Moreover, the current study suggests that the potential to add valence to information is modulated by people`s level of neuroticism, as discussed next.

Studies have shown that the regulation of emotions, particularly reappraisal, happens naturally and is strongly influenced by individual differences, such as age and anxiety (Garnefski & Kraaij, 2006a), working memory capacity (McRae, Jacobs, Ray, John, & Gross, 2012), self-esteem and optimism (Carver et al., 1989), and depression (Ehring et al., 2008). The results of the current study suggest this influence is also true for the other side of the coin – adding emotionality to neutral stimuli – with neuroticism playing an important role. This finding is somewhat in line with one by Fulcher et al. (2001), who looked into the effects of acquired emotion on attention. In the first phase of their study, participants saw neutral images paired with negative or positive sentences. In the second phase of the experiment, participants completed a probe detection task, where the images were used to create attentional interference. Results showed that the level of neuroticism explained why some participants were equally affected by the two types of images, whereas others became slower with negative pictures. This suggests that some people have an intrinsic tendency to transfer negative emotion from one item to another. Similarly, in the current study, participants with higher levels of neuroticism were the ones who added more negative emotions into their stories.

It is interesting that the other personality traits do not seem to have significantly influenced participants' response. As mentioned in the previous paragraph, previous studies have found correlations between positive reappraisal and traits such as optimism and self-esteem (Carver et al., 1989). So, it is possible that some personality traits are involved in emotion regulation, and others are involved in emotion attribution.

Conclusion

In conclusion, this study investigated how natural it is to add emotionality to neutral information and whether that is influenced by personality traits. On average, participants created stories that were more negative than the original words, but that were still within the neutral range. This tendency was positively correlated with their neuroticism scores. These findings suggest that personality traits have an impact on how participants process task stimuli and this should be considered in further studies. More specifically, the findings of the current study also have empirical implications for EC studies. Most studies do not use neutral items as a base line, directly comparing negative and positive emotions (e.g. Gast & Kattner, 2016; Halbeisen et al., 2014).The current study suggests that future research should, indeed, measure EC after negative or positive pairing with the neutral condition.

Experiment 4.2: Memory and evaluative conditioning effects of voluntary versus forced emotion attribution

The data for this experiment were in part collected by Heer Shah, a student on the UCL Medicine BSc in the 2015/16 year, as part of his final undergraduate project.

Introduction

Experiment 4.1 revealed that people tend to add negativity to sentences created with neutral words, although the effect is not enough to change the valence of the sentence. The next studies in this thesis look at how experimental manipulations affect participants' natural tendency of emotion attribution. The aim of the current experiment was to investigate if EC effects differ when participants are explicitly told to attribute emotions to neutral information from when they are free to decide when to do so. Because the previous experiment found effects of neuroticism on emotion attribution, personality tests were also included in the current study.

As mentioned earlier in this chapter, voluntary shifts of emotions are related to mental health. More specifically, Ehring et al. (2010) found that depressive patients usually show difficulties in changing the emotional status of an event unless directly instructed to do so, in which case they are as efficient as control participants. The authors proposed that depression is related to difficulty in selecting the appropriate type of emotion regulation strategy to be used, but not in actually using the strategies. These findings are important for suggesting that explicit instructions as to how one should regulate emotions may lead to findings that do not correspond to what happens outside of the lab.

Only one previous study has looked at EC effects when the emotional US is either presented by the experimenter or chosen by each participant. Fulcher et al. (2001) conducted two experiments in which they presented participants with neutral pictures of flower pictures and asked them to form a mental image involving the picture and a word. For half of the trials, negative, neutral and positive words were provided by the experimenter. For the other half, participants chose words that related to positive, negative or neutral situations recently experienced. After that, a likeability task for the flowers and a source memory task for the words were completed. The findings of the first experiment showed a non-significant trend (p < .070) for EC effects to be larger for trials in which participants generated the emotional words. However, the second experiment did not show a hint of this effect. Although the authors do not discuss these findings, they suggest that voluntary emotion attribution may have different effects on EC when compared to a forced condition.

Additionally, Fulcher et al. (2001) compared their results between low and high-neuroticism participants and found that this personality trait has no influence on the likeability task. Experiment 4.1 of this thesis suggested that neuroticism does influence how people attribute emotions to information. Thus, more investigation is needed to unveil the effects of personality traits on emotion attribution and EC.

Therefore, the present study altered the EC procedure commonly used in the literature to include neutral words that should be used to create either neutral or positive sentences. The encoding phase (from now on referred to as phase 1) had two conditions. In one condition, the words were preceded by facial cues indicating whether the sentences should be of neutral or positive valence. In the other condition, the words were preceded by an exclamation mark, and participants could decide when to create a neutral or a positive sentence. This encoding task served as a conditioning task, in which the neutral words were paired with the emotional sentences created by each participant. During retrieval (phase 2), participants saw old and new words and should indicate which type of sentence (positive or neutral) had been created with that word in the previous phase. In the likeability task (phase 3), participants rated how much they liked or disliked each word presented individually. This phase served as a measurement of EC, i.e. whether neutral words paired with positive sentences would be more liked than neutral words paired with neutral sentences, demonstrating that those words acquired the emotional status of the paired sentences.

Only positive and neutral valences were used in this study because a pilot test indicated that the use of three valences would make the test session too long and tiring. The reason that positive rather than negative valence was chosen is that older adults are better than younger adults in emotion regulation, especially positive reappraisal, which means they are generally better in reinterpreting events as positive (Shiota & Levenson, 2009; Urry & Gross, 2010). Although the current study does not test older adults, ageing is the focus of this thesis, so the protocol was devised with that population in mind. Additionally, it has been shown that cognitive strategies to change the emotional status of an event are more spontaneous and frequent when they involve making the event more positive than negative (Volokhov & Demaree, 2010).

Two fundamental differences between the protocol used in the current experiment and the one used in the majority of EC studies should be discussed. Firstly, the number of repetitions during encoding is known to influence memory performance (reviewed by Hintzman, 1976). Thus, to avoid this confounding factor in the analyses of the relationship between memory and EC, the current study presented each word only once. This differs from the majority of EC studies, which present the US-CS pairs several times. Thus, if EC effects are found in this study, this protocol can be used by other researchers in future experiments to avoid effects of repetition. Moreover, many real-life situations involve only single encounters of emotional-neutral pairs, making the protocol used here more ecologically valid.

The second difference is that most EC studies use external US and, in this study, the US are imagined sentences that were not provided to participants at any point. This was done because, from a practical point of view, it is not possible to rule out that some results in Chapter 3 were caused by perceptual differences between neutral and negative/positive images. That is, neutral images are usually composed of unitary and simple elements, whereas negative and positive images commonly depict richly complex visual scenes. As discussed in experiment 3.1, older adults have greater difficulty in discriminating images that are ambiguous or complex (Ryan et al., 2012; Scheerer & Marrone, 2014), which may lead to lower memory performance for such stimuli (McDonough et al., 2014). Moreover, encoding-activity in experiment 3.1 and 3.2 showed an unusual posteriorly-distributed negativity for neutral images (similar to findings by Dolcos & Cabeza, 2002), that may potentially have been caused by the different features of neutral and negative/positive images, rather than by the valence itself. Thus, to avoid perceptual differences between stimuli, the current study and the following studies in this thesis used sentences imagined by the participants as emotional stimuli. Additionally, with the ageing factor in mind, imagined sentences were chosen because older adults show high performance in reimagining events as positive (Urry & Gross, 2010), making it likely they would be able to do the task, and this thesis was interested in age-related differences in EC.

Therefore, this study's aim was twofold: to compare spontaneous with forced emotion attribution in a relatively novel EC procedure, and to analyse possible influence of individual differences on the effects. It was predicted that EC effects would be present in the forced condition, but would be larger in the voluntary condition, in accordance with the suggestion made by Fulcher et al. (2001). The influence of personality traits such as neuroticism could either replicate Fulcher et al. (2001)`s data or the results of experiment 4.1.

Methods

Participants

Thirty-eight adults (28 females, mean age = 20.97 ± 3.51 years) volunteered to take part in this study. The self-esteem questionnaire and the Big Five Inventory were administered.

Procedure

Phase 1 (Figure 4.2.1) worked as an incidental encoding task and also as a conditioning task. Participants were exposed to neutral words one at a time. The task was to create a sentence using that word and press a button on a response box when done. The sentences should be spoken out loud to be recorded on a Sony ICD-PX333 voice recorder. Phase 1 was composed of two conditions. Each condition was presented in two encoding blocks of forty trials each. In the *told* condition, each word was preceded by a cue that indicated the emotional valence of the sentence to be created. In the *free* condition, there were no facial cues, and every word was preceded by an exclamation mark. In that condition, participants were free to choose whether to create a neutral or a positive sentence. The order of presentation of the blocks was counterbalanced across participants. Within the told blocks, positive and neutral trials were intermixed in a randomised order. In phase 1, a trial consisted of a cue presented for 1500ms, followed by 100ms of blank screen, and then a word that was shown for 5000ms. The time in between trials varied randomly from 1500 to 3000ms, during which time a white fixation cross was showed. Before starting the conditioning task, participants completed five practice trials. Those were done to ensure participants had understood the task and were creating appropriate sentences. At the end of phase 1, participants had a ~10 minute break, in which they responded to the neurocognitive questionnaires.

At the end of the break, participants were told their memory was about to be tested. In phase 2, participants were once again presented with words, one at a time, but this time the words were preceded by a simple exclamation mark in the same font and size as the words. Phase 2 consisted of a source memory task, in which participants had to discriminate between old words and new words. In the cases when participants thought the word was old, they were asked to indicate whether they remembered the valence of the sentence created with that word during phase 1. Participants pressed one of four buttons to indicate their response (old+positive, old+neutral, old+unsure, new). The responding fingers were counterbalanced across participants. As detailed in Chapter 2, a source memory task was chosen for the EC experiments because previous literature looking into the brain activity during retrieval of neutral information encoded in an emotional context advocates for the use of source memory tasks rather than remember/know tasks (Maratos & Rugg, 2001; Smith, Dolan, et al., 2004). In phase 2, a trial consisted of a fixation cross presented for 1000ms, followed by an exclamation mark presented for 800ms, followed by 100ms of blank screen, and then a word that was shown for 2500ms. Participants responded to 4 blocks of 40 trials each. The time in between trials varied from 1500 to 3000ms.

In phase 3, participants had to decide how much they liked or disliked each word presented. The decision was made on a 1 to 9 scale (1 being absolutely dislike and 9 being absolutely like) using the computer keyboard and index finger. This time, the words were not preceded by faces and remained on-screen until a response was given. Participants responded to one self-paced block of 200 trials. The session time for this experiment was of approximately 1,5 hour.

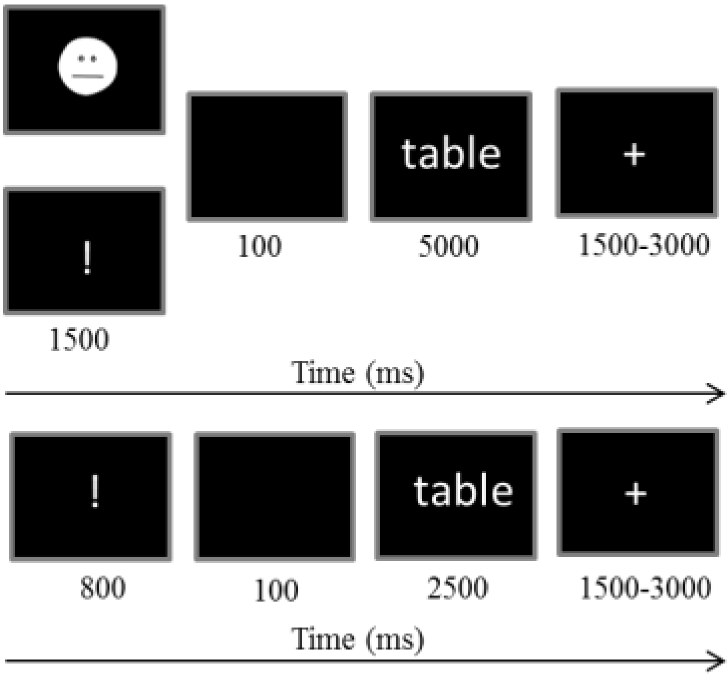

Figure 4.2.1. Trial sequence during encoding and test phases.

The top image represents encoding, when participants should speak a sentence containing the given word. Encoding was divided into two conditions. In the told condition, the words were preceded by facial cues and the sentences should follow the valence indicated. In the free condition, the words were preceded by an exclamation mark and participants could choose whether to create a neutral or a positive sentence. The bottom image represents retrieval. In this phase, participants should judge whether each word had been presented in the previous phase and which valence had been associated with it. In the last phase of the experiment, not depicted, participants saw all the words one by one and should indicate how much they liked or disliked each one.

Words used as stimuli

The words were selected as explained in Chapter 2. The cues preceding each word during the “told” condition in phase 1 were schematic happy and neutral faces. The cue preceding the words in the “free” condition was an exclamation mark in the same font, size and colour as the words.

As can be seen in Figure 4.2.2, words were allocated to different phases of the experiment. Some words were presented in all phases and were used for the main EC analyses (in the Figure, these are represented in the boxes with red outlines). However, because studies have shown that higher likeability ratings are given to items that are seen for longer, regardless of their acquired valence (Stahl, Haaf, & Corneille, 2016; Zajonc, 1968), some words were present in only part of the phases. These words were used in a preliminary analysis to rule out number of presentations as a confounding factor in the EC results.

Data analyses

The audio recordings were heard by two experimenters (myself and Heer Shah) who classified the sentences created in the “free” condition as positive or neutral. Thus, all data were divided into four categories: positive sentences created in the told condition (told-positive), neutral sentences created in the told condition (told-neutral), positive sentences created in the free condition (free-positive), and neutral sentences created in the free condition (free-neutral). The analyses used this classification.

Memory data were assessed by comparing performances in phase 2 for the two conditions and for the two emotional valences according to Pr values. These behavioural measures were submitted to repeated-measures ANOVA with condition (free and told) and emotional valence (positive and neutral) as factors. Response bias was not calculated in this study because only one measure of false alarm was available since all the new words were neutral and preceded by an exclamation mark.

The analyses of EC effects were done in two steps. Firstly, as mentioned before, the effects of number of presentations were tested to investigate if likeability ratings had been influenced by words being presented in more than one experimental phase. This was done via repeated-measures ANOVA with four levels: words presented only once (purple box, in the right column of Figure 4.2.2), words presented twice (red box), words presented twice, including the conditioning phase (blue box without red outline), and words presented three times and later used in the main analysis (blue box with red outline). The yellow boxes and the green box without the red outline were not used in the preliminary analyses.

Secondly, the main analysis was conducted between words presented in all three phases (boxes with red outlines in Figure 4.2.2). This was a repeated-measures ANOVA with four levels: told-neutral (blue box), told-positive (green box), free words (yellow box) used in positive sentences, and free words used in neutral sentences.

The personality traits accessed via questionnaires were correlated with EC effects to investigate individual differences.

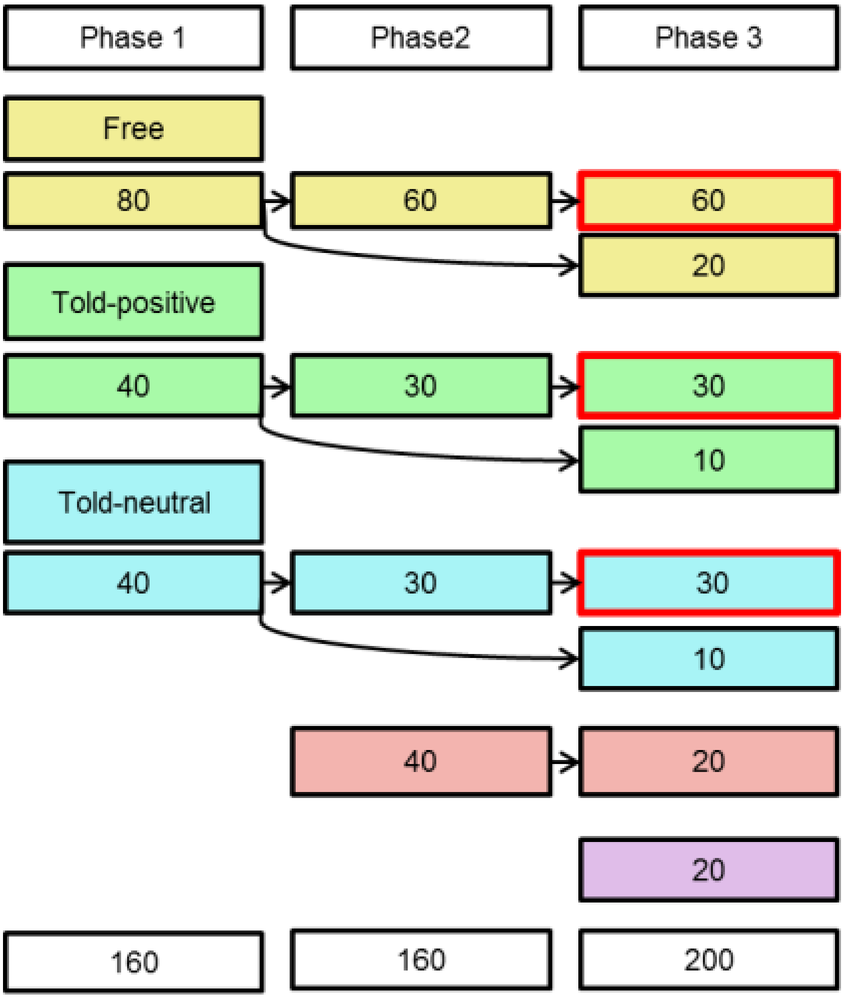

Figure 4.2.2. Experimental design and stimuli allocation.

This image represents how the words were allocated to the different experimental phases. The bottom line reflects the total words presented in each phase. Words in phase 3 were used to calculate EC effects. The boxes with red outlines represent words used in the main analysis, since those were presented in all phases. The other words presented in phase 3 were used for preliminary analyses in order to exclude the confounding factor of number of presentations.

Results

Six participants were excluded from the analyses for not following the instructions or for not creating any positive sentence in the "free" condition. The mood questionnaire scores and the behavioural performance scores led to the same statistical results regardless of whether the analyses were done with 38 or 32 participants. Therefore, only the latter are presented. Scores for the Big 5 and the Self-esteem questionnaires are presented in Table 4.2.1.

Table 4.2.1. Mean scores on the personality and self-esteem questionnaires.

	Mean
Self-esteem/4	3.00 (.42)
Openness/5	3.69 (.55)
Consciousness/5	3.09 (.65)
Extraversion/5	3.27 (.66)
Agreeableness/5	3.71 (.57)
Neuroticism/5	3.08 (.84)

The numbers after the name of the questionnaire represent the maximum score in that questionnaire. Numbers in parentheses are standard deviations.

Study phase

From the audio recordings, it was possible to analyse how many sentences participants chose to make positive in the free condition. On average, participants created 24.00 (SD = 9.35) positive sentences, and 51.75 (SD = 10.41) neutral sentences. In 4.25 (SD = 4.67) trials, participants either created a negative sentence, or did not speak. A paired samples t-test revealed that the neutral sentences outnumbered the positive sentences created in the free condition ($t_{(32)} = -8.160$, $p < .001$).

Since the number of positive sentences largely varied between participants, this value was correlated with the scores obtained from the Self-esteem and the Personality questionnaires in order to test if individual differences in those parameters could explain the observed results. The analyses revealed a significant positive correlation with Self-esteem, i.e. participants with more elevated self-esteem created more positive sentences from the neutral words ($r = .511$, $p = .003$, with Holm correction $p = .036$).

Memory task

The complete data for source and item Pr can be seen in Table 4.2.2.

The ANOVA for source memory Pr revealed no main effects of condition (p = .063) or valence (p = .407). However, the two factors interacted ($F_{(1,31)}$ = 5.974, p = .020, η^2_p = .162). Further t-tests revealed that this interaction was caused because the told-neutral condition elicited better performance than the free-neutral condition ($t_{(32)}$ = 3.613, p = .001). No comparison between positive and neutral conditions elicited significant effects (p > .089). Thus, in the current study, no mnemonic advantage for positive trials was found. Item memory Pr revealed no effects (p > .365).

Table 4.2.2. Memory performance and discriminability indices for source and item memory in each condition and emotional valence.

	Positive	Neutral
Old items, told condition		
Source hit	66.3(2.0)	66.3(25.0)
Source wrong	14.0(13.7)	12.3(19.0)
Source unknown	6.7(1.1)	6.3(25.0)
Miss	6.7(6.7)	5.0(5.7)
Old items, free condition		
Source hit	66.6(25.5)	58.3(26.6)
Source wrong	17.0(18.1)	21.3(22.0)
Source unknown	3.3(8.1)	7.3(14.4)
Miss	3.6(6.7)	3.5(14.9)
New items		
Correct rejections	91.5(10.2)	
False alarms	5.5(9.0)	
Indices, told condition		
Pr Source	.60(.22)	.61(.28)
Pr Item	.80(.14)	.79(.17)
Indices, free condition		
Pr Source	.60(.27)	.53(.28)
Pr Item	.80(.18)	.81(.16)

Numbers in parentheses are standard deviation. Pr = discrimination index. Data after exclusion of no-response trials.

Likeability task

As explained in the methods section, a preliminary analysis was conducted to assess possible effects of repetition on likeability. The repeated-measures ANOVA revealed a significant effect of presentation (F(3,81) = 2.840, p = .043, η^2_p = .096). Tests of within-subject contrasts comparing words later used in the main analysis (blue box with red outline) with the other words did not reveal significant differences (p > .121). Thus, it is reasonable to assume that the following main analysis was not biased by words having been presented more than once.

The main analyses (conducted with words represented by boxes with red outlines in Figure 4.2.2) revealed main effects of condition (F(1,31) = 21.598, p < .001, η^2_p = .411), of emotional valence (F(1,31) = 17.936, p < .001, η^2_p = .367) and also an interaction between the two factors (F(1,31) = 4.895, p = .034, η^2_p = .136). The main effects show that words from the free condition were more liked than the ones from the told condition and that words used in positive sentences were more liked than words used in neutral sentences, confirming EC effects. The interaction between the factors was analysed by comparing the strength of EC effects between the two conditions, which is, by comparing the difference between ratings for words encoded in positive sentences and words encoded in neutral sentences. The results revealed that EC effects were significantly larger in the free condition than in the told condition (t(31) = -2.212, p = .034). A graphic representation of the EC effects can be seen in Figure 4.2.3.

Because the previous study in this chapter found that neuroticism is related to the addition of negativity into neutral information, the personality traits were again correlated with the strength of EC effects. A negative correlation was found between agreeableness and the strength of EC effects in the free condition (r = -.470, p = .007). A positive correlation was found between self-esteem and the strength of EC effects in the free condition (r = 353, p = .047). However, these effects did not survive after Holms correction (p > .084).

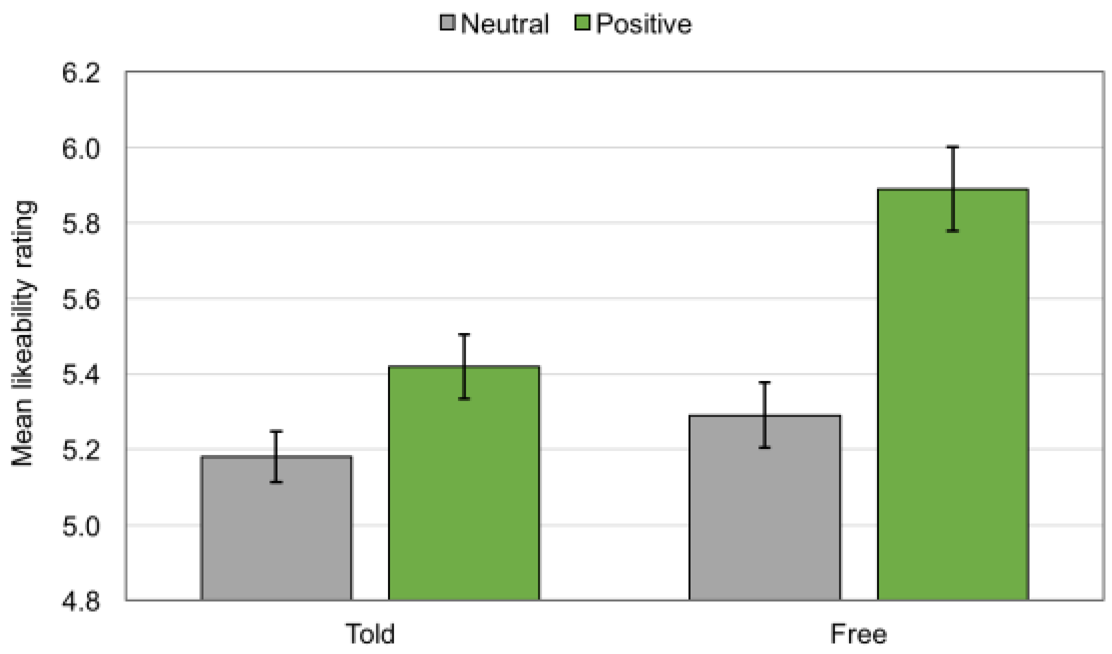

Figure 4.2.3: Mean likeability ratings per experimental condition.
Mean ratings and SEs given for words used in neutral (grey) and positive (green) sentences from the told and free conditions. EC effects were significant in both conditions, but the strength of the effect was significantly larger in the free condition.

Discussion

The aim of the current study was to investigate memory and EC effects when participants are told which emotion to attribute to a word as compared to when they are free to choose so. The results of the told and free conditions showed that the procedure developed in this thesis is successful in eliciting EC effects. However, there was no memory benefit from attributing positive emotions to words.

The likeability ratings for words used in positive sentences were larger than for neutral words used in neutral sentences. This finding suggests that the EC procedure in the current study worked. That is, constructing a positive sentence with a neutral word once was enough for that word to become more positive in valence. This is an important result, seeing that most EC studies in the literature pair neutral and emotional information many times. The experimental protocol used in this study may, after a few replications, be used by other researchers studying EC. This protocol will potentially decrease the length of an experimental session and allow researchers to use more stimuli, rather than the very few pairs commonly used in the EC literature. More stimuli will provide a more appropriate memory task in that memory will not be at ceiling.

Another important consideration of the current procedure having elicited EC effects is that there were no physically present emotional stimuli. The emotionality was mentally attributed by each participant. This supports the findings from De Houwer (2006), who also showed EC effects when participants were instructed about pairings but no pairings were shown. In that paper, the author instructed participants that two pseudo-words would be later paired with negative images and another two with positive images. The instructions asked participants to memorise that information. Following this, an implicit attribution task (IAT) was conducted, where those pseudo-words and negative/positive words were presented. The IAT results showed that the pseudo-words acquired the valence described in the instructions, even though the images were never actually displayed. The author raised the possibility that participants imagined the association between the pseudo-words and the future images and that imagined association was enough to generate EC effects. Those results were later replicated by Gast and De Houwer (2013), who added a new condition in which the US was actually present. No statistical differences in EC effects were found, in that study, between imagined and experienced trials. The results of the current study expand the understanding of EC by showing reliable effects when the US is imagined but not physically present, as suggested by De Houwer (2006). Thus, it seems that internally generated emotions are an effective way of attributing emotions to neutral information. This suggestion has implications for advertisement and therapies that are based on EC by showing that the presence of external physical stimuli is not necessary for a change in liking.

The connection between imagery and emotion is not new. As reviewed by Holmes and Mathews (2010), clinical studies have already shown that excess or lack of imagery is linked to conditions such as anxiety, depression, and post-traumatic stress disorder. Additionally, a neuroimaging study (S.-E. Kim et al., 2007) suggested that imagining an emotional face elicits similar activity in the amygdala as looking at emotional faces, although no direct comparison was done between the two conditions. Another study showed that remembering an emotional event activates the amygdala similarly to imagining a future emotional event (Sharot, Riccardi, Raio, & Phelps, 2007). Thus, the current study offers further support for the proposal that imagining can indeed elicit emotional responses. The results shown here also suggest that this emotional activation may be transferred to another stimulus via evaluative conditioning, increasing stimulus' memorability.

In experiment 4.1, it was shown that participants with higher scores on neuroticism added more negative emotion to neutral information. In the current study it was shown that participants with higher self-esteem add more positive emotion to neutral information. Combined, these results suggest that individual differences have an impact on emotion attribution. This is interesting because it expands the literature on individual differences and emotion. As mentioned before, many studies have shown that personality traits affect emotion regulation (Gross & John, 2003; Hur et al., 2016). Particularly, it is known that people who voluntarily and spontaneously interpret negative events in a positive light show fewer symptoms of depression, higher well-being and higher social communication abilities (Ehring et al., 2008; Gross & John, 2003; John & Gross, 2004). In the current study, the results show that personality traits also influence emotion attribution. This finding attests for the importance of using questionnaires and matching different groups on their individual differences, at least personality traits, when studying emotion in its different shapes. Nevertheless, it is intriguing that neuroticism did not influence emotion attribution in the current experiment, as it did in experiment 4.1. This suggests that the effects of personality traits on emotion attribution may not be as reliable as their effects on emotion regulation.

The main aim of this study was to look at how EC effects would be affected by voluntary emotion attribution. The findings showed that although EC effects were significant in the told and in the free conditions, they were larger in the latter. These results are in line with the hint found by Fulcher et al. (2001) when comparing EC effects between an experimenter-provided US and participant-provided US. In that study, using an US chosen by the participants slightly increased EC effects. Three possibilities can be raised to explain these findings.

The first is that the free words used to created positive sentences were somehow already more positive to participants. On this account, the larger likeability effects were caused by previous differences in the CS and not by the EC procedure. In the debriefing questions, about half of the participants said they made positive sentences in the free condition if they already had a positive connection with that word. The other half reported creating the first sentence that came to mind, which was possibly implicitly associated with a positive experience from the past. Thus, it is possible that the larger EC effects in the free condition were a simple reflection of participants` pre-existing preference to some of the words. However, the lists of words designated to each condition were carefully matched for valence and arousal according to a validated database (Warriner et al., 2013). Moreover, if some of the words were already more positive than others, a memory effect would be expected. That is, participants would either show better source memory for those words because they are emotional (Doerksen & Shimamura, 2001), or they would use their feelings to guess the valence of the sentence with higher accuracy (Hutter et al., 2012). As already mentioned, no valence effects were found in memory performance in this study.

Another possibility to explain the larger EC effects in the free than in the told condition may be linked to attention. In the told condition, participants had to keep in mind the valence of the facial cue when creating the sentence. In the free condition, participants did not have extra information to attend to other than creating the sentences. So it is possible that the additional cognitive load posed by the cues limited how much attention was available during the creation of the sentences. This suggestion is supported by a study by Pleyers, Corneille, Yzerbyt, and Luminet (2009). These authors presented participants with a series of neutral objects superimposed on positive or negative images. In one condition, participants simply looked at the pairs, but in the other condition, participants had to simultaneously respond to an auditory numerical n-back task. The results showed that the addition of the secondary task during encoding significantly decreased EC effects. It is worth highlighting that in Pleyers et al. (2009)'s study, participants did not actively engage with the US-CS pairs. So, it is possible, that participants simply did not pay attention to the pairings when the secondary task was included. Not looking at the stimuli during encoding would reasonably reduce any later effects. In the current study, participants not only had to pay attention to the words, but also had to use them in a sentence. In fact, participants in the current study provided neutral or positive sentences for 94.3% of the free words, on average. Additionally, if participants had their attention divided in the told condition, a lower memory performance for that condition would be expected. That did happen in Pleyers et al. (2009)'s study but did not occur in the current study. Thus, although it is possible that the presence of the facial cues in the told condition distracted participants or took up some of their cognitive resources, this possibility is less likely due to the fact that participants were able to successfully engage with stimuli in all conditions.

A third possibility is that being free to choose when to attribute positive emotions to information changes how positive those emotions are. That is, it is possible that the valence rating of the free-positive sentences was more extreme than the ones of the told-positive sentences. Studies on non-verbal stimuli, such as laughter (Lavan, Scott, & McGettigan, 2016; McGettigan et al., 2015) and facial expressions (Krumhuber & Manstead, 2009), have shown that displays of positive emotion are rated higher in valence when they are spontaneous than when they are posed. Thus, it is reasonable to assume that this was also the case for the verbal stimuli in the current study. This idea is supported by the main condition effect found in the current study, where words from the free condition were more liked than words from the told condition. Additionally, a direct comparison of the likeability ratings reveals that words used in the free-positive sentences were more liked than the words used in told-positive sentences (p = .001). In the current study, although all sentences were generated by the participants, the freely generated ones elicited stronger EC effects. So, it is possible that when people are free to voluntarily attribute positive emotion to stimuli, they do it more intensively than when they are asked to do so, increasing later EC effects. An interesting suggestion would be to ask another group of participants to rate the sentences created according to valence and arousal, as was done in experiment 4.1.

A surprising result from the current experiment is that no differences were found between conditions or valence regarding memory performance. It was predicted that items with attributed emotion would be more memorable than the others, similar to what is usually seen for intrinsically emotional items (Buchanan, 2007; Hamann, 2001). However, the only effect found was better memory for neutral sentences from the told condition compared to neutral sentences from the free condition. This result is perhaps explained by the larger number of neutral sentences created in the free condition than in the told conditions. That discrepancy may have made the neutral sentences in the free condition more memorable for being less frequent and thus, more distinct (Bennion et al., 2013). Similarly, the differences in the number of positive and neutral sentences generated in the free and told condition may have masked the expected valence effects on memory performance. It can be argued that a more controlled free condition should be used in future studies, perhaps forcing participants to create an equal number of positive and neutral sentences. That would probably increase the statistical power of the analysis, by ensuring a considerable number of trials in each condition. However, that would defeat the purpose of the experiment, which was to have a more naturalistic condition, offering participants a voluntary choice. It is also possible that the null findings in memory performance between the valences were caused because the sentences were positive or neutral, but not negative. As detailed in Chapter 1, it is commonly found that younger adults remember negative events more than positive or neutral events (Baumeister et al., 2001; Rozin & Royzman, 2001). Thus, maybe there really are no differences between positive and neutral sentences, but negative sentences would have elicited better memory.

However, maybe the EC effects seen here were only present precisely because there were no explicit memory differences. As explained in Chapter 1, the Misattribution Theory suggests that EC effects happen when one confuses the source of emotion, misattributing the emotionality generated by one stimulus to the other (Jones et al., 2009). This theory also says that EC effects would happen only in the absence of explicit memory. Thus, it is possible that participants in the current study were not aware of the contingencies during study phase, which made them misattribute the valence of the sentence to the word.

Conclusion

The current study showed that individual differences, particularly self-esteem, can influence emotion attribution similarly to what has been seen in the emotion regulation literature. Moreover, this study used a new protocol in which the US is imagined and not physically present, and each US-CS pair is presented only once during encoding. Although the EC effects were present in the free and told conditions, the effects were enhanced when participants were free to decide when to attribute positive emotions. This may be caused because emotion attribution is more intense when done spontaneously, as previously shown with non-verbal stimuli. As mentioned before, the emotion regulation literature had already suggested that different instructions can lead to different results (Ehring et al., 2010). The current study shows that this also happens when emotions are added rather than removed. The current data allow the conclusion that, although EC effects in lab conditions are robust, they are larger during voluntary emotion attribution.

Chapter 5: Emotion attribution and memory in the ageing brain

This chapter contains two studies that are divided into three parts to provide a more logical progression of ideas. Initially, the behavioural results of the first study (named experiment 5.1) are presented and discussed as an initial step towards understanding emotion attribution and evaluative conditioning in older adults. Then, the second study (named experiment 5.2) is presented and discussed, since it contains behavioural manipulations that investigate the relationship between memory and evaluative conditioning in ageing. Lastly, the ERP data of the first study (renamed as experiment 5.3) are presented and discussed to suggest a possible neural mechanism underlying evaluative conditioning and the interactions between emotion attribution and episodic memory.

Experiment 5.1: Emotion attribution and evaluative conditioning in older adults

Introduction

Experiment 4.2 showed that the EC procedure used in this thesis is successful in altering the likings towards neutral information. That is, participants were able to attribute emotional status to neutral information. Interestingly, this emotion attribution did not influence memory performance. The current chapter continues to investigate emotion attribution and memory, but also includes older adults as participants. As mentioned in Chapter 1, very little research has been done looking at EC in ageing, so it is unclear how EC manifests across the lifespan.

The few studies that have looked at EC in ageing show mixed results. Blessing et al. (2013) paired unfamiliar faces with liked, disliked or neutral faces and later tested participants in a memory task and in a likeability task. The results revealed that older adults showed no EC effect, because they showed no differences between the liking of faces paired with the positive or negative stimuli. Results also revealed that older adults' memory performance was at chance level. However, the authors acknowledge that 11 of the 14 participants seemed to show a regular EC effect, while the remaining 3 showed a reverse effect. Thus, it is possible that the null result was caused by low sample power. In another study, Olson et al. (2013) argue that their results show a larger EC effect in older adults compared to younger adults despite similar performance on the memory task between the age groups. However, no statistical comparison between the two age groups was performed in that study, so it is not clear how – and even if – EC effects manifest in ageing and what their relationship is with memory.

Similar to the procedure used in experiment 4.2, the current experiment had three phases. During phase 1 (encoding), younger and older adults saw neutral words preceded by facial cues that indicated whether the sentences created should be positive or neutral. Unlike experiment 4.2, phase 1 of the current experiment had only one condition. Phases 2 (retrieval) and 3 (likeability) were conducted exactly as the previous experiment.

It was expected that older adults would show a general lower performance on the memory task, as evidenced in the source memory literature (Hedden & Gabrieli, 2004; D. C. Park & Gutchess, 2005). As in experiment 4.2, it was predicted that the words paired with positive sentences would be more liked than the ones paired with neutral sentences. As a consequence, words that gain positive valence should be better remembered than the ones that remain neutral. It was unclear whether the effects would be different between younger and older participants, and that was the primary question of interest.

Methods

Participants

Thirty-three younger adults ([YA], 26 females, mean age = 22.3±3.1 years) and thirty-one older adults ([OA], 27 females, mean age = 71.7±5.3 years) volunteered to take part in this study. The state-trait anxiety inventory, the Beck Depression Inventory, and the Big Five Inventory were administered to assess comparability across age groups.

Procedure

Participants sat comfortably in a chair that was within arm distance from the monitor screen and completed three phases of the experiment (Figure 5.1.1). EEG was recorded during these phases. The EEG procedures will be explained when describing experiment 5.3 later in this chapter.

Phase 1 was conducted in the same way as the “told” condition of experiment 4.2. Participants were exposed to neutral words one at a time. The task was to create a sentence using that word and press a button on a response box when done. The sentences should be thought but not spoken to avoid EEG movement artefacts. Each word was preceded by a cue that indicated the emotional valence of the sentence to be created. The instructions for phase 1 emphasized that participants should use the cues to prepare to make a sentence with the upcoming word. Positive and neutral trials were intermixed in a randomised order. In phase 1, a trial consisted of a fixation cross presented for 1000ms, followed by a valence cue presented for 1500ms, followed by 100ms of a blank screen, and then a word that was shown for 5000ms. The time in between trials varied randomly from 1500 to 3000ms. Participants responded to five blocks of 40 trials each. Before the beginning of the task, all participants completed five practice trials in which the sentences should be spoken out loud to ensure they had understood the task. At the end of phase 1, participants had a ~10 minute break, in which they completed the mood questionnaires.

Phase 2 was done as in experiment 4.2. Participants saw old and new words and should indicate whether they remembered the valence of the sentence created with that word. Participants pressed one of four buttons to indicate their response (old+positive, old+neutral, old+unsure, new). The responding fingers were counterbalanced across participants. In phase 2, a trial consisted of a fixation cross presented for 1000ms, followed by an exclamation mark presented for 800ms, followed by 100ms of a blank screen, and then a word that was shown for 2500ms. Participants responded to four blocks of fifty trials each. The time in between trials varied from 1500 to 3000ms. At the end of phase 2, the EEG cap was removed.

After the cap had been removed, phase 3 began, which measured EC effects. In this phase, participants decided how much they liked or disliked each presented word, by selecting 1 to 9 on the computer keyboard. The words were not preceded by faces and remained on-screen until a response was given. Participants responded to one self-paced block of 230 trials. The session time for this experiment, including the EEG capping described in experiment 5.3, was approximately 3 hours.

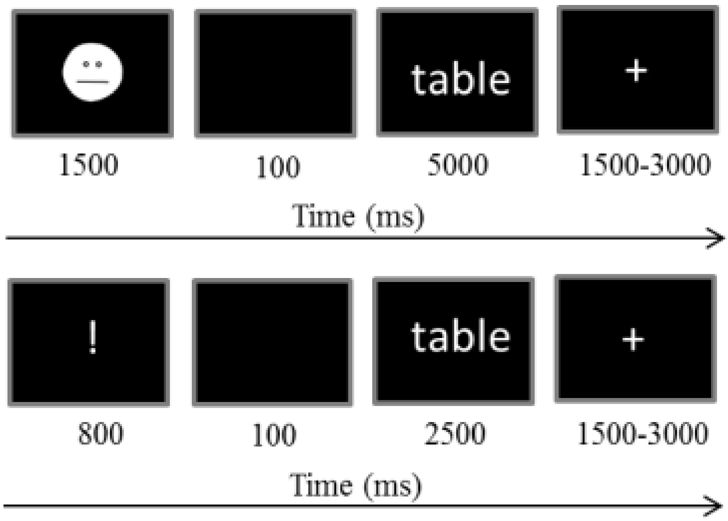

Figure 5.1.1. Trial sequence during encoding and retrieval phases.
The top image represents phase 1. In this phase, participants were presented with facial cues that indicated whether participants should create a neutral or a positive sentence with the upcoming word. The bottom image represents phase 2. In this phase, participants should judge whether each word had been presented in the previous phase and which valence had been associated with it. All words were preceded by an exclamation mark. In phase 3, not depicted, participants saw all the words one by one and should indicate how much they liked or disliked each one. Phase 3 was self-paced.

Words used as stimuli

The words were selected as explained in Chapter 2. The cues preceding each word in phase 1 were schematic happy and neutral faces. The cue preceding the words in phase 2 was an exclamation mark in the same font, size and colour as the words.

As can be seen in Figure 5.1.2, similar to what was done in experiment 4.2, words were allocated to different phases of the experiment. Some words were presented in all phases and were used for the main EC analyses (in the Figure, these are represented in the boxes with red outlines). Other words were presented in only part of the phases. These words were used in a preliminary analysis to rule out number of presentations as a confounding factor in the EC results.

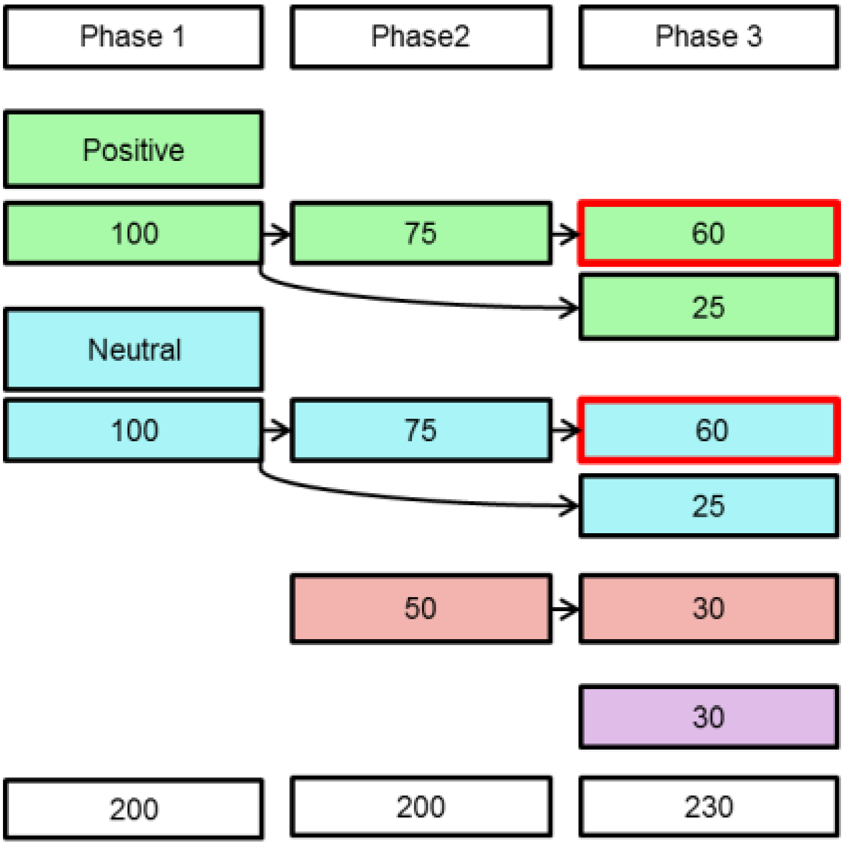

Figure 5.1.2. Experimental design and stimuli allocation.
This image represents how the words were allocated to the different experimental phases. The bottom line reflects the total words presented in each phase. Words in phase 3 were used to calculate EC effects. The boxes with red outlines represent words used in the main analyse, since those were presented in all phases. The other words presented in phase 3 were used for preliminary analyses in order to exclude the confounding factor of number of presentations.

Data analyses

Source memory Pr was computed separately for positive and neutral items during the memory task and then submitted to a mixed-model ANOVA with age as a between-subjects factor and emotional valence as a within-subjects factor. The same procedure was done for Source memory Br.

The analyses of EC effects were done in two steps. First, as mentioned before, the effects of number of presentations were tested to investigate if likeability ratings had been influenced by words being presented in more than one experimental phase. This was done via an ANOVA with four levels: words presented only once (purple box, in the right column of Figure 5.1.2), words presented twice (red box), words presented twice, including the conditioning phase (blue box without red outline), words presented in all phases and later used in the main analysis (blue box with red outline). The green boxes were not used in this preliminary analysis. All analyses also included age as a between-subjects factor.

Secondly, the main analysis was conducted between words presented in all three phases (boxes with red outlines in Figure 5.1.2). This was an ANOVA with the factor valence divided into two levels: neutral (blue box) and positive (green box). This analysis also included age as a between-subjects factor.

Results

The results are based on the 24 YA and 23 OA kept for the ERP analyses in experiment 5.3 to enable comparisons between the two types of data.

Mood questionnaires

YA and OA did not differ on their scores for most of the mood questionnaires (Table 5.1.1). The only score in which age groups differed was Extraversion, with older adults being more extraverted than younger adults.

Table 5.1.1. Mean scores on the mood questionnaires.

	Young adults	Older adults	Statistical comparison
Depression/20	6.3(5.3)	8.4(5.8)	t(45) = -1.326, p = .191
Anxiety trait /80	39.3(6.1)	38.7(9.7)	t(45) = .290, p = .773
Anxiety state /80	31.5(7.6)	29.5(6.3)	t(45) = .967, p = .338
Openness/5	3.4(.7)	3.5(.7)	t(45) = .934, p = .599
Consciousness/5	3.9(.6)	3.8(.5)	t(45) = .759, p = .452
Extraversion/5	3.4(.6)	3.8(.6)	t(45) = -2.399, p = .021
Agreeableness/5	3.0(.6)	2.8(1.1)	t(34.52) = .937, p = .355
Neuroticism/5	3.9(.6)	4.2(.5)	t(45) = -1.981, p = .054

The numbers after the name of the questionnaire represent the maximum score in that questionnaire. Numbers in parentheses are standard deviations. The degrees of freedom of the Agreeableness comparison were corrected because those scores did not pass Levene’s test for equality of variances.

Study phase

The response time to create sentences during the study phase was compared between valences and age groups. YA took, on average, 3753ms (± 576) for positive trials and 3346ms (± 526) for neutral trials. For OA, the times were 3724ms (± 655) and 3444ms (± 604), respectively. Mixed-model ANOVAs revealed a main effect of valence, with participants being quicker to create neutral sentences than positive sentences ($F(1,45) = 37.214$, $p < .001$, $\eta^2_p = .453$). Interestingly, no age differences were found, suggesting that YA and OA did not differ in perceived difficulty of the task.

Likability task

As explained in the methods section, a preliminary analysis was conducted to assess possible effects of repetition on likeability. A mixed-model ANOVA was done with age as a between-group factor, and number of presentations as a within-group factor. There was no effect of presentation ($p = .072$) or interaction with age ($p = .198$). Thus, it is sensible to assume that the main analysis was not biased by the words having been encountered before.

The main analyses (conducted with words represented by boxes with red outlines in Figure 5.1.2) revealed a strong effect of valence ($F(1,45) = 8.954$, $p = .004$, $\eta^2_p = .166$) and no effect of age nor interaction between factors ($p > .304$). This shows that neutral words used in positive sentences were more liked than neutral words used in neutral sentences. A graphic representation of the EC effects can be seen in Figure 5.1.3.

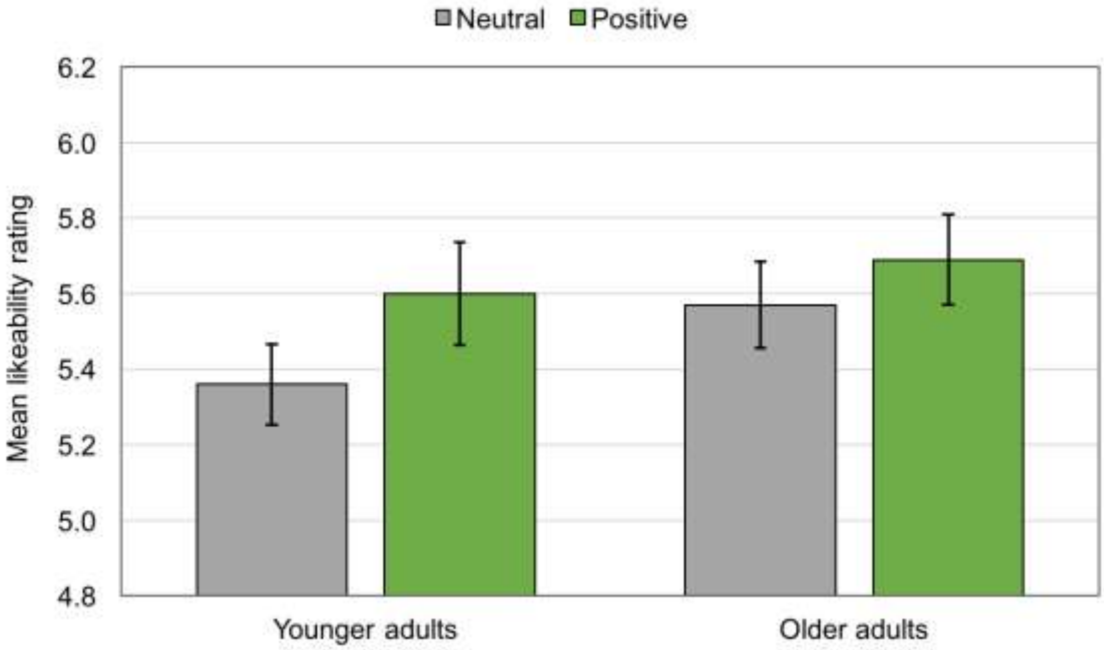

Figure 5.1.3. Mean likeability ratings by age group and experimental condition. Ratings given by younger and older adults for neutral words used in neutral (grey) and positive (green) sentences. Bars represent standard errors. Words used in positive sentences received higher ratings than words used in neutral sentences, with no interaction with age.

Memory task

For source memory (Table 5.1.2), the analyses revealed a main effect of valence ($F(1,45) = 10.103$, $p = .003$, $\eta^2_p = .183$), with memory for positive source being higher than for neutral source. No effect of age or interaction between the factors was found ($p > .052$). Item memory revealed no effects ($p > .158$). Response bias showed a main effect of valence, being larger for positive than for neutral trials ($F(1,45) = 5.300$, $p = .026$, $\eta^2_p = .105$), but was not influenced by age (p > .516).

Table 5.1.2. Memory performance (%) of younger and older adults for words encoded in positive and neutral sentences.

	Younger adults		Older adults	
	Positive	Neutral	Positive	Neutral
Old items				
Source hit	59.6(10.9)	52.0(16.7)	51.5(14.0)	44.1(19.9)
Source wrong	8.7(6.8)	13.1(8.7)	19.2(10.1)	22.9(13.7)
Source unknown	19.6(8.4)	21.3(11.6)	13.7(12.3)	17.5(14.9)
Miss	11.5(7.6)	13.1(10.0)	13.9(10.3)	14.3(8.3)
New items				
Correct rejections	87.6(11.4)		83.4(12.4)	
False alarms	12.4(11.2)		15.8(12.6)	
Indices				
Pr Source	.51(.14)	.39(.22)	.32(.19)	.21(.29)
Pr Item	.75(.14)	.74(.16)	.69(.15)	.69(.14)
Br	.20(.14)	.19(.12)	.23(.15)	.21(.14)

Numbers in parentheses are standard deviation. Pr = discrimination index; Br = response bias. Data after exclusion of no-response trials.

In summary, the procedure used in this experiment was successful in eliciting EC effects. That is because words used in positive sentences were more liked than words used in neutral sentences. The words from positive trials were also better remembered than the ones used in neutral trials. No significant interaction between those effects and age was found.

Discussion

The current study investigated the presence of evaluative conditioning in older adults, as well as its effects on episodic memory. Similar to experiment 4.2, the current results clearly show EC effects, with words used in positive sentences being more liked than words used in neutral sentences. This experiment also reveals no statistical difference between the age groups in relation to EC effects. This result suggests that emotion attribution is a preserved ability in healthy ageing. This suggestion goes against the findings from Blessing et al. (2013), who found no EC effects in older adults, and against Olson et al. (2013), who found larger EC effects in ageing. As mentioned in the introduction, those two pieces of research are not optimal in their statistical approach, such as having outliers and not directly comparing the groups of participants. The current experiment, thus, provides a more robust evidence for the similarity between younger and older adults in their EC effects. Nevertheless, this result needs to be replicated in order to allow firm conclusions about the role of ageing on EC. Additionally, the studies by Blessing et al. (2013) and Olson et al. (2013) used physical emotional stimuli, so it is possible that the different results between the current study and those two were caused by methodological particularities.

It is also important to note that Blessing et al. (2013) and Olson et al. (2013) used negative stimuli as well as positive ones. As detailed in Chapter 1, older adults are competent in shifting the valence of an event to make it more positive (Shiota & Levenson, 2009; Urry & Gross, 2010). Thus, it is unclear what the results of the current experiment would be if participants had been asked to create negative sentences. Following from the Socioemotional Selectivity Theory (Carstensen et al., 1999), it is possible that EC effects would be smaller in older adults when imagining negative sentences. It is also possible that older adults would have difficulty creating the negative sentences, or would create less arousing sentences. Those questions should be addressed with qualitative analyses of the sentences generated and, perhaps, a free recall memory task.

The current experiment revealed that attributing positive emotions to neutral information enhances episodic memory for this information. Source memory for the sentences was significantly higher for positive sentences when compared to neutral ones. This result is in accordance with previous literature that has found an increase in source memory for neutral items encoded in contexts of different emotional valences (Maratos & Rugg, 2001; Smith, Dolan, et al., 2004; Smith, Henson, Dolan, & Rugg, 2004; Smith, Henson, Rugg, & Dolan, 2005). Importantly, in all those studies, the emotional context was visually presented as an image. In the current study, the emotional context was mentally created by each participant. Thus, the findings of the current study suggest that subjectively added emotionality elicits similar effects on source memory as a physically presented emotional stimuli.

This result differs from what was found in experiment 4.2. It is possible that the interaction of EC and memory are not as robust as the isolated EC effects. In that experiment, the presence of a free condition may have changed how participants engaged with the told condition. So, it seems like attributing positive emotions to neutral information enhances memory performance only under certain conditions that remain to be clarified. Additionally, the design that was used does not allow causal or mediatory conclusions. In other words, it is not possible to know whether the increase in memory led to the increase in likeability, or vice versa, or if emotion attribution has a twofold effect. Therefore, studies that manipulate memory performance are necessary to shed light on this question. This issue will be further discussed in the next experiment, which actively manipulated memory performance.

Importantly, there were no effects of ageing on memory performance in the current study. This suggests that younger and older adults do not differ in how their memory and attitudes are influenced by emotion attribution. This is the first study to investigate EC in older adults and the results are encouraging. An increased understanding of EC is already being applied to treatments of post-traumatic stress disorder (Engelhard, Olatunji, & De Jong, 2011), for example. Likewise, Dulas et al. (2011) showed that older adults` memory performance benefits from the use of self-referential processing. Thus, if positive emotion attribution is related to memory in older adults, as suggested by the current study, this could be used by this population as a mnemonic technique and help their common memory deficits, or as clinical treatments.

Conclusion

In conclusion, this was the first study to empirically evaluate EC in older adults, showing that the effects of positive emotion attribution in memory and likeability do not differ in ageing. Moreover, the current study supports the suggestion from experiment 4.2 that the protocol used in this thesis is successful in eliciting EC effects. Future research could use this methodology to improve the memory associated with the EC literature.

Experiment 5.2: Effects of repetition and delay on evaluative conditioning and memory of younger and older adults

The pilot data for this experiment were in part collected by Camellia Belal, an A-level student in 2016, as part of her In2ScienceUK summer internship programme.

Introduction

The previous experiment showed that younger and older adults can attribute positive emotions to neutral information. The results also showed that neutral words paired with positive emotions were better remembered. However, the exact relationship between EC and memory is still not clear. Studies that specifically manipulate one factor to evaluate the other one may allow more concrete suggestions as to how EC relates to memory.

For example, a few studies have manipulated encoding in an attempt to have a more direct measure of the relationship between memory and EC. Fulcher and Hammerl (2001) asked one group of participants to complete a distracting arithmetic task during encoding, whereas the other group received a detailed explanation about EC and the aims of the study. With this design, the authors expected to decrease memory performance in the dual-task group and analyse if EC effects would also be decreased. Interestingly, results showed that, actually, only the dual-task group displayed EC effects, despite lower memory performance. However, the type of manipulation used by Fulcher and Hammerl (2001) likely increased demand awareness, which may have biased the study (Lovibond & Shanks, 2002). In contrast, Pleyers et al. (2009) and Dedonder, Corneille, Yzerbyt, and Kuppens (2010) gave a secondary/distractor task to one group, whereas the control group only performed the main encoding task. The results showed that EC effects were present in the control group and not in the distractor task group. Richter and Gast (2017) tested how increasing the temporal spacing between conditioning repetitions during encoding would influence EC. Spacing is known to increase memory performance (Cepeda et al., 2006) and in Richter and Gast (2017)'s study, it also increased EC effects. The authors suggest that EC and memory are based on similar cognitive processes. Studies involving directed forgetting or memory suppression have reached similar conclusions (Gast & Kattner, 2016; Molet et al., 2016). The aim of the current study was to expand this literature by investigate how EC and episodic memory are influenced when the encoding conditions and the retrieval conditions are manipulated via stimulus repetition and study-test delay.

This investigation is important because Hofmann et al. (2010) conducted a meta-analysis of 214 studies and showed that EC is a robust and consistent effect. However, the authors conclude that more studies are necessary to understand the boundaries of the effect and how each variable/modulator interacts with one another in the context of EC. Besides that, if EC is to be used in therapy or in marketing, it is crucial to understand in which circumstances it occurs (Baeyens et al., 1992; Fulcher et al., 2001; Stuart, Shimp, & Engle, 1987).

In experiment 5.1, results showed the presence of evaluative conditioning in younger and older adults and its enhancing effect on memory using a novel protocol. Because these findings are novel, they must be replicated and the conditions in which they occur must be tested. In the current study, a new group of younger and older participants completed a very similar task as the one in the previous chapter, but this time, the number of stimulus presentations during encoding and the study-test delay were manipulated. The encoding phase, or phase 1, was done like before, with the exception that half the words were presented three times rather than only once. Phases 2 and 3 were also the same as before, but they were repeated a week later when participants returned to the lab. The predictions for the study will be explained next.

As detailed in Chapter 1, early studies found an increase in EC with the repetition of study pairs (from 0 to 20 repetitions), but those were unexplained findings (Baeyens et al., 1992) or derived from methodological issues such as the exclusion of participants that showed contingency awareness or that simply did not show EC effects (Staats & Staats, 1959). Another study found a main EC effect with no change due to repetition when pairing fictitious brand names with positive images, however their control condition was a randomized presentation of all US and CS rather than pairing the brands with neutral images (Stuart et al., 1987). In the meta-analysis mentioned before, Hofmann et al. (2010) look at the influence of repetition on EC effects. They found a non-significant trend for a stronger effect with more repetitions. However, due to the small number of studies that had actually investigated this question, a stronger conclusion was not possible. Recently, Hu et al. (2017a) manipulated the number of repetitions of four pairs of fictitious pharmaceutical brands with positive or negative health-related conditions. Pairs were presented either eight or 24 times each. Results showed the presence of EC effects that were not influenced by the number of repetitions during encoding. In experiment 5.1, reliable EC effects were found after only one presentation.

In the current study, EC effects after repeated presentation could potentially be of two ways. Based on the trend found by Hofmann et al. (2010), EC effects should be found for items presented once but would be even stronger for items presented more times. However, based on the individual studies mentioned above, it could be found that EC will not change due to repetition.

With respect to delay, the early definition of EC claims the effect to be resistant to extinction (Baeyens et al. 1992). More recently, Forderer and Unkelbach (2013) presented participants with eight pairs of neutral faces and liked/disliked animals chosen by the participants themselves. The memory and the likeability tests were done on the same day and a week later. Although memory decreased after a week, EC effects did not. Using a four-week delay, Fulcher et al. (2001) found decreases in memory performance, but not in EC. In contrast, Gast, De Houwer, et al. (2012) paired 18 Chinese characters (unknown to participants) with positive, neutral and negative IAPS images. Memory and liking were measured 10 days after encoding. Results showed that EC was present only for items that were remembered. This study, however, did not test EC effects on the same day as encoding, so it is not possible to know whether it decreased with time. Using an even longer delay between the first and second sessions, Fulcher and Cocks (1997) also showed that, despite an 80% decrease in memory performance two months after encoding, the items that were recalled still showed similar EC effects as shown in the first session. These findings illustrate a direct relationship between memory (or contingency awareness) and EC, with the latter only present when there is memory. However, the results by Forderer and Unkelbach (2013) suggest that EC is a stable effect even with memory decreases. Although mixed, the results seem to indicate a general stability of EC. Thus, it was predicted that, in the current study, memory would decrease with delay but EC effects would not.

One important issue in the studies mentioned above is that they usually measure memory performance as a whole, without discriminating between different valences, which could provide further information about the relationship between memory and EC. Even more important to this thesis is that none of these studies investigated ageing. Outside of the EC literature, a couple of studies have tested younger and older adults` memories after a longer delay interval. Kalpouzos et al. (2008) found the same decline in memory performance for the two age groups. D. C. Park, Puglisi, and Smith (1986) found a stronger decline for older adults. However, these two studies had very different methodologies, with Kalpouzos et al. (2008) using incidental encoding, words and free recall, and D. C. Park et al. (1986) using intentional encoding, images, and recognition task. Thus, it is not possible to draw a general pattern from them. The literature on how repetition influences memory in ageing is also limited, with only one paper (Cohen, Sandler, & Schroeder, 1987) finding that, although younger adults outperform older adults, the benefit of repetition enhances memory in the two groups equally. The current study was interested in expanding this literature and also looking at the interaction between EC and memory in ageing.

As mentioned before, it was predicted that, for younger adults, repetition would increase memory and EC, whereas delay would decrease memory but not EC. The limited literature on how repetition and delay affect memory in ageing did not allow for specific predictions for the older adults in this study.

Methods

Participants

Thirty younger adults ([YA], 18 females, mean age = 22.2±2.82) and twenty-six older adults ([OA], 16 females, mean age = 71.4±5.12) took part in this study. The state-trait anxiety inventory, the Beck Depression Inventory, the self-esteem questionnaire, and the Big Five Inventory were administered to assess comparability across age groups. The information sheet and consent forms were read and signed at the beginning of the two sessions.

Procedure

During the first session, participants completed phases 1, 2 and 3 of the experiment. During the second session a week later, participants came back and completed phases 4 and 5.

Except for the presence of repeated words in phase 1, the experimental settings were exactly the same as experiment 5.1 (see Figure 5.1.1). During phase 1, the repeated words were presented three times with 20 to 70 trials between each other in order to avoid spacing effects, which have been shown to affect the strength and speed of conditioning (Gibbon & Balsam, 1981) and learning (Sisti et al., 2007). Participants were informed that some words would be repeated and that they should always create a sentence, but no specific instructions on the novelty of sentences was given. That is, participants could choose whether to always think of the same sentence or create a new one for each presentation of the same word. In phase 1, a trial consisted of a fixation cross presented for 1000ms, followed by a valence cue presented for 1500ms, followed by 100ms of blank screen, and then a word that was shown for 5000ms. The time in between trials varied from 1500 to 3000ms. Participants responded to four blocks of forty trials each. Participants also completed five practice trials, similar to what was done in experiment 5.1. At the end of phase 1, participants had a ~10 minute break, in which they responded to the neurocognitive questionnaires. The sentences were spoken out loud.

At the end of the break, participants were told their memory was about to be tested. This phase 2 was done exactly as in the previous experiment of this thesis. In phase 2, the words were presented only one time. Participants responded to two blocks of 55 trials each. Phase 3, the evaluative conditioning task, was also conducted exactly as in the previous experiment. All the words were presented only once in phase 3. Participants responded to one block of 125 trials. After the end of phase 3, participants went home without further explanations about the experimental goal. They were asked to not rehearse the words at home and to come back a week later.

Exactly seven days later, participants returned to the lab for the second session and to complete phases 4 and 5. Participants completed the State Anxiety questionnaire. Phase 4 was the memory task and conducted exactly as phase 2. Similarly, phase 5 was the evaluative conditioning task and conducted just like phase 3.

In this experiment, the first session time was approximately 1,5 hour and the second session time was approximately 1 hour.

Words used as stimuli

The words were selected as explained in Chapter 2. The cues preceding each word in phase 1 were schematic happy and neutral faces. The cue preceding the words in phase 2 was an exclamation mark in the same font, size and colour as the words. Figure 5.2.1 displays the word allocation in the current experiment, in accordance to what was done in experiments 4.2 and 5.1. Words in red outlines were used for the main analysis, whereas the others were used in a preliminary analysis to rule out effects of number of presentations. Importantly, “new” words used in the retrieval and likeability tasks in the first session were replaced by different words in the second session (represented by a * in figure 5.2.1).

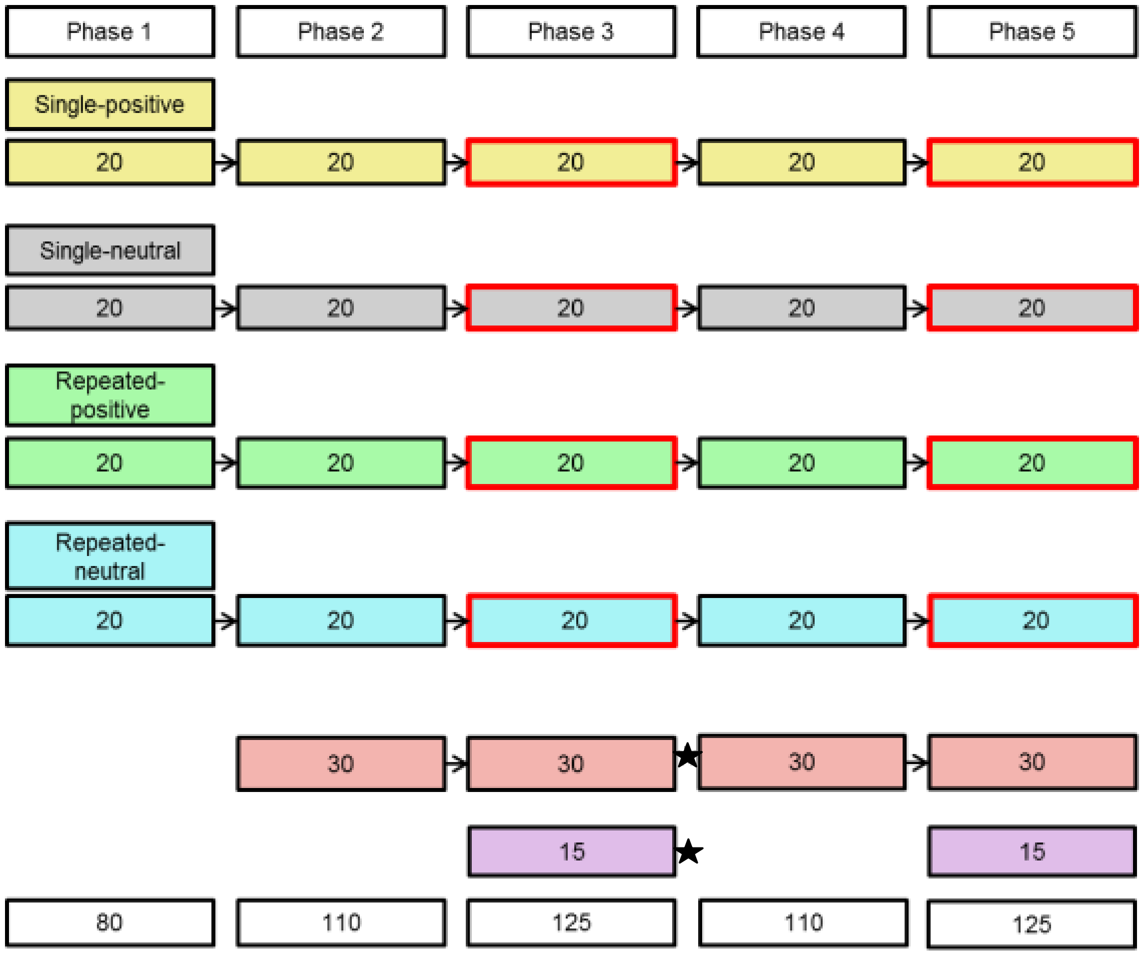

Figure 5.2.1. Experimental design and stimulus allocation.

This image represents how the words were allocated to the different experimental phases. The bottom line reflects the total words presented in each phase. Words in phases 3 and 5 were used to calculate EC effects in the first and second session, respectively. The boxes with red outlines represent words used in the main analyse, since those were presented in all phases. The other words presented in phases 3 and 5 were used in a preliminary analysis to test the effects of number of presentation. The star indicates that words in the red and purple boxes used in phases 2 and 3 were replaced by new words in phases 4 and 5.

Data analyses

For simplicity, and because repetition and study-delay manipulations were expected to have opposite effects on memory, and possibly EC, the data were initially analysed for each session individually and then compared for the relevant effects. Source memory Pr and Br were computed separately for positive and neutral items during the memory task and then submitted to a mixed-model ANOVA with age as a between-subject factor and emotional valence and number of repetitions as within-subject factors.

The analyses of EC were conducted in two steps. Firstly, to rule out effects of number of presentations on the likeability ratings, words presented only once (purple box) were compared to words presented twice (red box) and words presented in all phases, including the single-neutral conditioning phase (grey box). This was done for words in phase 3 and in phase 5, and included age as a between-subjects factor.

Secondly, the main analysis was conducted between words presented in all three phases (boxes with red outlines in Figure 5.2.1). This was a mixed-model ANOVA with valence and repetition as within-subject factors. This analysis also included age as a between-subjects factor.

Results

Mood questionnaires

Five YA and two OA were excluded from analyses for not following the instructions or for not returning for the second session. The mood questionnaire scores and the behavioural performance scores led to the same statistical results whether the analyses was done with 56 or with 49 participants. Therefore, only the latter are presented in Table 5.2.1. One OA did not complete the Anxiety Trait questionnaire. The age groups were similar in all tests except for openness, where OA scored higher. The scores on the Anxiety State questionnaire on the first session did not differ from the one on the second session (p = .209) and this was not influenced by age group (p = .504).

Table 5.2.1. Mean scores on the mood questionnaires.

	Young adults	Older adults	Statistical comparison
Depression/20	8.76(9.12)	6.12(4.78)	t(36.6) = .468, p = .211
Anxiety trait /80	39.96(11.99)	37.70(10.23)	t(46) = .701, p = .487
Anxiety state 1st session /80	33.08(10.69)	28.83(8.26)	t(47) = 1.553, p = .127
Anxiety state 2nd session /80	30.92(7.80)	28.17(6.56)	t(47) = 1.334, p = .189
Self-esteem/4	3.32(.52)	3.25(.40)	t(47) = .466, p = .644
Openness/5	3.46(0.69)	4.00(0.61)	t(47) = -2.914, p = .005
Consciousness/5	3.69(0.62)	3.62(0.78)	t(47) = .341, p = .735
Extraversion/5	3.17(0.69)	3.28(0.55)	t(47) = -.593, p = .556
Agreeableness/5	3.90(0.58)	3.93(0.57)	t(47) = -.202, p = .841
Neuroticism/5	2.79(0.94)	2.68(0.76)	t(45) = .484, p = .644

Numbers in parentheses are standard deviations. The degrees of freedom of the Depression comparison were corrected because those scores did not pass Levene's test for equality of variances.

First session

A main effect of repetition was found on source memory Pr (F(1,47) = 81.898, p < .001, η^2_p = .635), with repeated items leading to better source memory than single items (Table 5.2.2). A main effect of age was found (F(1,47) = 4.196, p = .046, η^2_p = .082) with YA outperforming OA. No main effect of valence was found (p = .329), but this factor interacted with repetition (F(1,47) = 8.250, p = .006, η^2_p = .149). This interaction was driven by positive items eliciting better performance than neutral items for the repeated condition (F(1,47) = 11.512, p = .001, η^2_p = .197), but not for single one (p = .671).

Regarding item memory Pr, a main effect of repetition was found (F(1,47) = 55.921, p < .001, η^2_p = .543), with repeated items leading to better memory than single items. A main effect of age was found (F(1,47) = 4.230, p = .045, η^2_p = .083) with YA outperforming OA. An interaction between repetition and age group was also found (F(1,47) = 4.686, p = .036, η^2_p = .091). Follow-up analyses showed the effect of repetition to be present in both YA (F(1,24) = 33.130, p < .001, η^2_p = .580) and OA (F(1,47) = 28.662, p < .001, η^2_p = .555). No main effect of valence was found (p = .670).

Response bias showed only a main effect of repetition (F(1,47) = 14.170, p < .001, η^2_p = .232), and no other effects (p > .176), with the bias for repeated items larger than for single items.

Table 5.2.2. Memory performance (%) of younger and older adults with words encoded in neutral and positive sentences in the first session of the experiment.

	Younger adults		Older adults	
	Positive	Neutral	Positive	Neutral
Old, single items				
Source hit	62.0(22.5)	64.0(25.0)	50.0(22.0)	50.5(24.0)
Source wrong	9.5(9.0)	9.0(12.0)	20.0(10.0)	19.0(17.5)
Source unknown	14.0(16.5)	12.0(15.0)	5.5(10.5)	6.0(13.5)
Miss	8.0(7.5)	9.0(8.0)	11.0(12.0)	11.5(12.5)
Old, repeated items				
Source hit	85.5(17.0)	78.5(21.0)	77.0(24.5)	67.0(24.5)
Source wrong	4.0(5.0)	9.0(11.0)	11.5(12.5)	23.5(21.0)
Source unknown	5.0(10.5)	7.0(12.0)	6.0(18.5)	1.0(3.0)
Miss	2.0(4.5)	1.0(2.5)	1.0(2.0)	1.0(2.5)
New items				
Correct rejections	93.7(7.3)		91.0(19.7)	
False alarms	3.3(4.0)		6.7(17.0)	
Indices, single items				
Pr Source	.58(.24)	.61(.27)	.44(.30)	.44(.32)
Pr Item	.82(.11)	.82(.13)	.69(.23)	.69(.22)
Br	.07(.09)	.09(.11)	.08(.16)	.08(.13)
Indices, repeated items				
Pr Source	.82(.18)	.77(.18)	.71(.35)	.61(.33)
Pr Item	.91(.09)	.92(.07)	.88(.20)	.85(.22)
Br	.19(.24)	.16(.22)	.14(.21)	.13(.25)

Numbers in parentheses are standard deviation. Pr = discrimination index; Br = response bias. Data after exclusion of no-response trials.

Regarding EC effects, the preliminary analysis revealed no differences in terms of number of presentations (p = .134).

The main analysis revealed a strong effect of valence ($F(1,47) = 41.678$, $p <$ .001, $\eta^2_p = .470$) with items used in positive sentences being more liked than items used in neutral sentences. A main effect of repetition was also found, with repeated items being more liked than single items ($F(1,47) = 7.299$, $p = .010$, $\eta^2_p = .134$). No effects of age or interaction between factors were found ($p > .072$). Due to the difference in memory performance between the younger and older adults, each age group was analysed individually for EC effects. Both groups showed significant EC effects [YA: $F(1,24) = 26.798$, $p < .001$, $\eta^2_p = .528$; OA: $F(1,23) = 15.936$, $p = .001$, $\eta^2_p = .409$]. A graphic representation of the EC effects can be seen in Figure 5.2.2

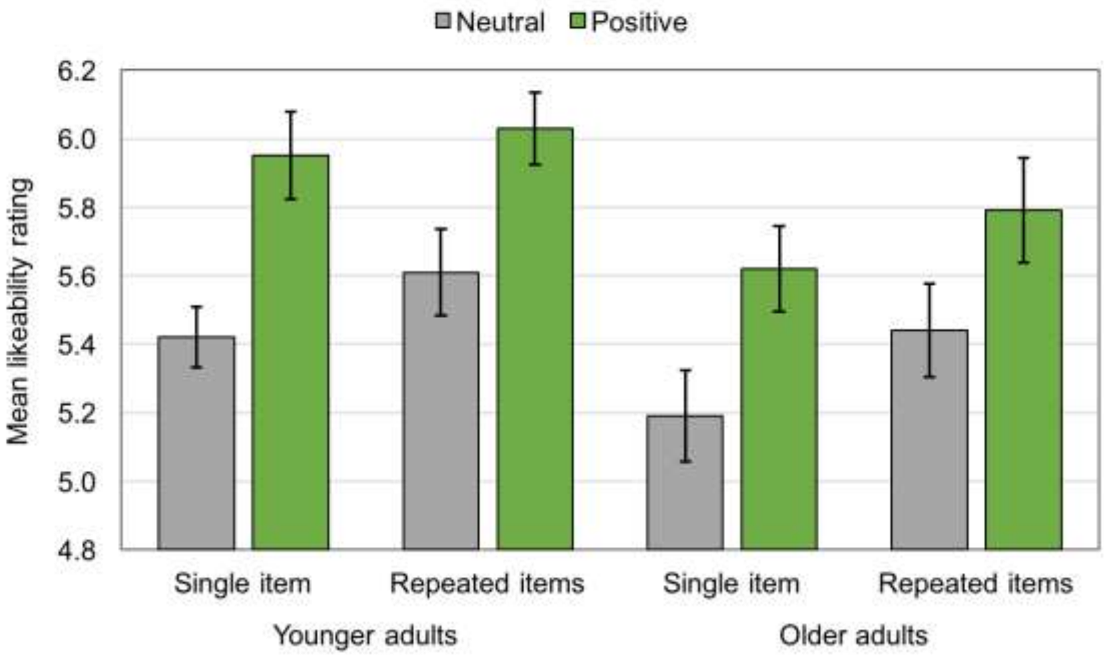

Figure 5.2.2. Mean likeability ratings per condition and age group in the first session of the experiment.
Mean likeability ratings for single and repeated words used in neutral (grey) or positive (green) sentences by younger and older adults. Bars represent SE.

Second session

Regarding the source memory Pr data (Table 5.2.3), a main effect of repetition was found ($F(1,47) = 85.075$, $p < .001$, $\eta^2_p = .644$), with repeated items leading to better memory than single items. No age effects were found ($p > .128$). No main effect of valence was found ($p = .865$), but this factor interacted with repetition ($F(1,47) = 15.507$, $p < .001$, $\eta^2_p = .248$). Follow-up analyses for single and repeated items, however, revealed no effects of valence ($p > .142$).

Regarding item memory Pr, a main effect of valence was found ($F(1,47) = 7.960$, $p = .007$, $\eta^2_p = .145$), with words used in positive sentences being better remembered than words used in neutral sentences. A main effect of repetition was also found ($F(1,47) = 74.524$, $p < .001$, $\eta^2_p = .613$), with repeated items leading to better memory than single items. A main effect of age was found ($F(1,47) = 4.929$, $p = .031$, $\eta^2_p = .095$) with YA outperforming OA.

Response bias showed a main effect of repetition (F(1,47) = 32.891, p < .001, η^2_p = .412). Valence did show have a main effect (p > .653) but interacted with repetition (F(1,47) = 4.587, p = .037, η^2_p = .089). The main effect reveals that response bias was higher for repeated items compared to single items. The interaction was investigated by looking at each valence separately. The effects of repetition were found in both neutral (F(1,47) = 10.073, p = .003, η^2_p = .176) and positive (F(1,47) = 32.230, p < .001, η^2_p = .407) items. No effects of age were found (p > .370).

Table 5.2.3. Memory performance (%) of younger and older adults with words encoded in neutral and positive sentences in the second session of the experiment.

	Younger adults		Older adults	
	positive	neutral	positive	neutral
Old, single items				
Source hit	25.0(18.5)	29.0(25.0)	22.5(19.5)	27.5(23.0)
Source wrong	16.5(15.0)	15.0(13.0)	26.0(16.0)	15.0(14.5)
Source unknown	29.0(21.5)	25.5(20.5)	18.5(20.0)	18.5(20.5)
Miss	25.0(14.5)	25.0(15.0)	26.0(16.5)	28.5(16.0)
Old, repeated items				
Source hit	50.0(24.5)	41.5(30.5)	41.0(25.0)	37.5(26.0)
Source wrong	14.0(12.5)	17.5(17.0)	23.5(19.0)	24.0(18.5)
Source unknown	21.5(23.0)	20.5(23.0)	17.0(21.0)	17.0(21.5)
Miss	9.0(8.0)	14.0(14.0)	10.0(11.5)	12.5(9.0)
New items				
Correct rejections	84.3(12.3)		76.0(22.3)	
False alarms	13.7(11.3)		20.0(22.0)	
Indices, single items				
Pr Source	.11(.23)	.15(.30)	.01(.2)	.08(.30)
Pr Item	.57(.18)	.56(.19)	.46(.18)	.41(.15)
Br	.15(.10)	.16(.11)	.19(.18)	.20(.19)
Indices, repeated items				
Pr Source	.36(.26)	.28(.35)	.21(.30)	.17(.34)
Pr Item	.72(.15)	.66(.19)	.62(.23)	.58(.23)
Br	.22(.16)	.19(.14)	.24(.21)	.23(.22)

Numbers in parentheses are standard deviation. Pr = discrimination index; Br = response bias. Data after exclusion of no-response trials.

Regarding EC effects, the preliminary analysis revealed no differences in terms of number of presentations (p = .325).

The main analysis revealed a strong EC effect was present ($F(1,47) = 18.875$, $p < .001$, $\eta^2_p = .287$) with items used in positive sentences being more liked than items used in neutral sentences. A main effect of repetition was also found, with repeated items being more liked than single items ($F(1,47) = 20.616$, $p < .001$, $\eta^2_p = .305$). No effects of age were found ($p > .117$). A graphic representation of the EC effects can be seen in Figure 5.2.3.

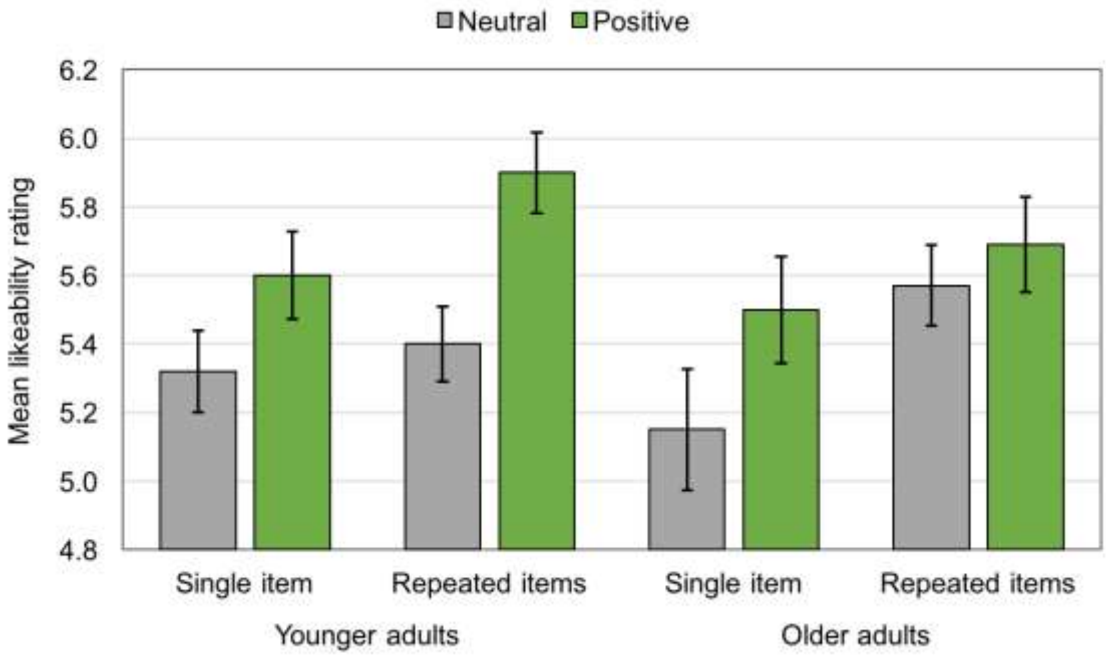

Figure 5.2.3. Mean likeability ratings per condition and age group in the second session of the experiment.

Mean likeability ratings for single and repeated words used in neutral (grey) or positive (green) sentences by younger and older adults. Bars represent SE.

Since neither of the sessions showed a significant interaction between valence and repetition or age in EC effects, a final analysis was conducted to directly compare EC strength of unique items with that of repeated items. For that, the ratings for the first and second session of all participants were combined for each valence and conditions. Then, the values for neutral items were subtracted from the values for positive items to calculate EC strength (De Houwer, 2007; Gawronski & Mitchell, 2014). These values were compared in a paired sample t-test to determine if the strength of the EC effects was affected by the repetition manipulation. The results showed no differences between EC strength between unique and repeated items ($p > .455$), confirming no effects of repetition on that measure.

First session versus second session

Since both sessions showed strong EC effects that were not modulated by repetition or age, the EC strength was compared between the first and the second session regardless of those factors. The effect was significant $t(48) = 2.017$, $p = .049$ (two-tailed). This means that the EC effects were stronger on the first session (.43±.46) than on the second session (.31±.50).The interaction with age was not significant ($p = .523$).

Additionally, to confirm the decline in memory performance with an increased delay, source memory was combined across single and repeated items and then compared with valence and delay as within-subject factors and age as a between-subjects factor. The results showed a strong main effect of delay ($F(1,47) = 170.637$, $p < .001$, $\eta^2_p = .784$), with no effects or interaction with valence or age group ($p > .356$).

In summary, during the first session, the memory manipulation was successful, since repeated items were markedly better remembered than single items. As expected for source memory paradigms, YA outperformed OA. Additionally, repetition affected source memory performance, since only repeated items elicited better memory for positive than neutral words. In opposition, repetition did not affect EC effects, which were large for both YA and OA. During the second session, the mnemonic advantage of repeated items was maintained. However, this was no longer accompanied by better source memory for words used in positive sentences compared to words used in neutral sentences. Additionally, source memory for the two age groups was similar in the second session. Importantly, EC effects were still present during the second session, but in smaller than in the first session.

Item-based analyses

As explained in Chapter 1, Pleyers et al. (2007) argued that a more adequate way of investigating contingency awareness in EC is to conduct item-based analyses. They suggest that, instead of contrasting memory performance and likeability ratings for positive and neutral trials, the memory judgments should be used for the likeability contrasts. In other words, the likeability ratings should be contrasted according to the trial type and whether the item was remembered or forgotten. In that paper, Pleyers et al. (2007) demonstrate that the results can be qualitatively distinct when trial-based and item-based analyses are conducted.

Thus, in the current study, an item-based analysis was conducted in addition to the ones already mentioned. The likeability ratings were compared between positive and neutral trials for words that received a correct source judgment and for words that received an incorrect source judgment. If memory and EC are truly related, EC effects should only be present when participants remembered the emotional source of the word. There were not enough trials to conduct this analysis while taking repetition and study-test delay into account. Likeability ratings were, thus, combined across all positive trials on the one hand and all neutral trials on the other, regardless of repetition or delay. For each, ratings were contrasted for trials receiving correct and incorrect source judgment.

The four values obtained (positive-correct, positive-incorrect, neutral-correct, neutral-incorrect) were compared in an ANOVA with age as a between-subject factor. The results showed a highly significant interaction between memory and valence (F(1,47) = 40.838, p < .001, η^2_p = .465). When looking at correct and incorrect source memory judgments individually, paired sample t-tests indicated that EC effects were present for both [correct: t(48) = 6.887, p < .001; incorrect: t(48) = -3.509, p = .001], but in opposite directions. In other words, items that received a correct source judgment showed a regular EC effect, with words used in positive sentences being more liked than words used in neutral sentences. Items that received an incorrect source judgment showed a reverse EC effect, with words used in neutral sentences being more liked than words used in positive sentences. No effects of age were found (p > .296), however, given the primary interest in the study, each age group was also analysed separately. The same pattern found in the global analysis was found for YA (p < .001) and for OA (p < .001), confirming the presence of the link between memory and EC in the two age groups.

These analyses suggest a strong link between memory and EC. The items that participants correctly remember the valence of the sentence created show a strong EC effect. The items that participants remember the opposite valence show a strong reverse EC effect. This pattern can be visualised in Figure 5.2.3.

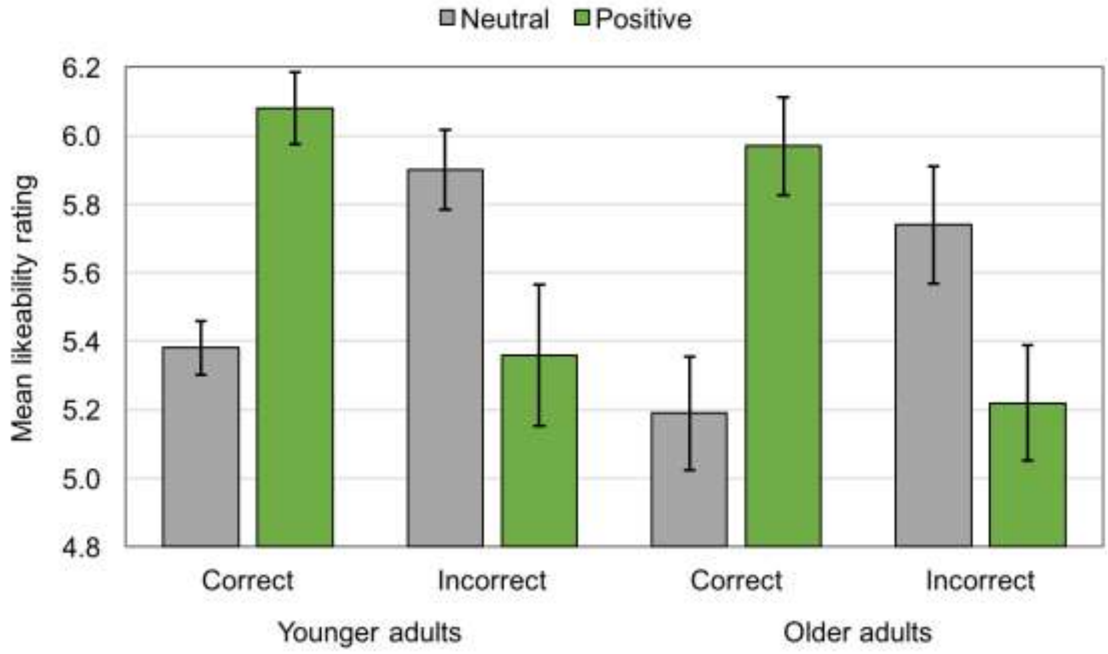

Figure 5.2.3. Mean likeability ratings per age group according to source memory. Mean likeability ratings given by younger and older adults for words used in neutral (grey) and positive (green) conditions, according to whether a word had its source remembered or not. Bars represent SE.

Discussion

The results of the current study replicated the ones from the previous study in showing that younger and older adults are able to attribute positive emotions to neutral items. The results also offer further support for the EC procedure developed in this thesis to be useful for future studies. That is, pairing a neutral stimulus with an imagined emotional context once is enough to alter the likeability rating of that neutral stimulus.

As expected, repeating stimulus presentations during encoding increased source memory performance. Also as expected, memory after one week was lower than memory after a few minutes. Importantly, none of these effects interacted with ageing, suggesting that repetition and delay have similar effects in the two age groups, as shown by Cohen et al. (1987) and Kalpouzos et al. (2008). These results confirm that the memory manipulations used here were successful. Thus, the remaining discussion will focus on how those manipulations influenced EC effects.

Repetition and Delay

Although repeated items were generally more liked than single items (cf. Stahl et al., 2016; Zajonc, 1968), no interaction between repetition and EC was found. This result is in line with a few previous studies (Hu et al., 2017a; Stuart et al., 1987) and suggests that, once emotion has been attributed, its effects on liking are not altered by additional stimuli presentations. Another possibility is the variability of the sentences created by the participants in the current study. In the debrief questions, the vast majority of participants reported having remembered the previous sentence created with a repeated word and actively tried to create a new one, although not always being successful. This information may be relevant given Stahl and Unkelbach (2009)`s study on EC effects after single or multiple US. These authors found that presenting a CS always with the same US produced larger EC effects than when the US had the same valence but different identities, possibly because contingency awareness (measured via memory tasks) was reduced in the latter condition. Interestingly, Hofmann et al. (2010)`s meta-analysis showed no reliable differences in EC effects due to the use of single or multiple US identities. In the current study, a mix of single and multiple US was present, since participants imagined the same US by recalling it but also imagined a new one. It is not clear how this may have affected EC effects due to repetition. Future studies should perhaps have two groups of participants and instruct them to either create the same sentence every time or a new one. This may help arbitrate between Stahl and Unkelbach (2009)`s and Hofmann et al. (2010)`s findings.

EC effects were present in the first and in the second sessions. However, the difference between likeability ratings given to positive and to neutral items decreased with a longer study-test delay. This result suggests that memory and EC effects decrease with a long delay, differing from a previous study in the literature (Forderer & Unkelbach, 2013). One difference between that study and the current one is that they used images as US and CS. It is possible that EC effects from visual images last longer than the ones from imagined sentences. However, another issue is that that study did not use neutral US. In other words, EC effects were calculated as the difference between likeability ratings of positive and negative trials. Actually, previous studies have reported differences in EC between negative and positive trials despite the latter not being statistically different from neutral trials (Schacht, Adler, Chen, Guo, & Sommer, 2012; Wieser et al., 2014). Thus, it is impossible to know if the effects from Forderer and Unkelbach (2013) would survive in comparison to a neutral condition.

The results of the current study, reporting no effect of repetition on EC but a significant decrease over a week’s delay, are important. Firstly, from a methodological point of view, this finding may optimise the procedure used in future studies. This is because most EC studies use several pairings during conditioning, as reviewed in Chapter 1. By showing that EC effects are present even after a single presentation and do not enhance with representation, the procedure used here may be utilised in future studies. Secondly, as mentioned before, EC has the potential to be used in clinical and advertisement settings. Early definitions of EC claimed the effect to be resistant to extinction (Baeyens et al., 1993). However If, as suggested by this thesis, EC effects are not long-lasting, the applicability in those contexts may be reduced.

Item-based analysis

Following the suggestion by Pleyers et al. (2007), the current study also conducted an item-based analysis to evaluate the relationship between memory and EC in a more direct way. Although there was not enough statistical power to investigate the role of repetition and delay, it was possible to compare EC effects between items that elicited a correct source judgment and items that elicited an incorrect source judgment. The results of this analysis strongly point to a direct relationship between memory and EC. Items that had their source correctly remembered showed a large EC effect, but items that showed the opposite source judgment revealed a large reverse EC effect.

It may be tempting to conclude, like others have (Gast, De Houwer, et al., 2012; Pleyers et al., 2009; Ruys & Stapel, 2009; Stahl & Unkelbach, 2009), that this result supports the precondition of memory to EC. However, some authors highlight that this is a correlational result and not a causal one (Gast, Gawronski, & De Houwer, 2012; Gawronski & Walther, 2012). According to these authors, it is possible that when participants remember the valence of the sentence, they like the word more. But it is equally possible that they use their attitudes towards the words to give a memory judgment. That is, participants may guess the source of the word based on how much they like it. Hutter et al. (2012) argue a similar idea after building a mathematical model that takes into account participants` memory and attitudes. These authors suggest that EC is formed by a propositional process and by an attitudinal learning irrespective of explicit memory, supporting the associative-propositional evaluation model, explained in Chapter 1 (Gawronski & Bodenhausen, 2006).

It is possible that part of the effects seen in the current study is due to participants using their preferences to answer the memory task. However, the two studies described in this chapter have several methodological differences in comparison to the vast majority of EC studies in the literature. The first difference is the presence of older participants. This group is known for lower source memory and that was, indeed, found in the studies reported here. However, no age-related differences in EC effects were found. This suggests that a general memory decline is not necessarily related to smaller EC effects. On the other hand, participants performed markedly worse during the memory test on the second session of the current study, and EC strength decreased accordingly. Following these patterns, the item-based analysis seemed like a fair idea to assess the relationship between memory and EC. On that matter, another fundamental difference between this thesis and other EC studies is that here, between 80 and 120 unique CS were used, rather than about 25 as in the other studies. The large number of items makes the memory task more difficult, which could force participants to base their memory judgments on their feelings towards the words, enhancing the affective bias described above (Gast, Gawronski, et al., 2012; Gawronski & Walther, 2012; Hutter et al., 2012). However, participants in the current experiment (and experiments 4.2 and 5.1) had a “don`t know” option during retrieval, which should be used in case they were in doubt of their response, decreasing the probability of guessing (Smith et al., 2005). Thus, the current study clearly points to a relationship between memory and EC, although the causal effects remain unknown. Future studies should apply the methodology used here in a more demanding task in order to have enough trials and participants for each repetition and delay conditions. This may help understand the relationship between EC and memory. Moreover, previous literature has shown the relationship between memory and EC to be dependent on stimulus novelty (Ruys & Stapel, 2009). Thus, it is possible that repeated items would show a different pattern during the item-based analysis when compared to single items.

Conclusion

In conclusion, the memory manipulations used in the current study were successful in increasing performance with repetition during study and decreasing performance with a longer study-test delay. The results on EC effects were not so clear-cut. Repetition did not influence EC, but EC effects a week later were significantly smaller than immediately after encoding. This suggests that a decrease in memory is accompanied by a decrease in EC, but that one single presentation during encoding is enough to elicit EC and more presentations do not increase such effects. Interestingly, although older adults showed reduced source memory performance, no age-related differences were found in EC. On the one hand, this suggests that a general decrease in memory performance is not always connected to lower EC. On the other hand, it replicates the previous study in this thesis showing that younger and older adults are able to attribute positive emotion to neutral words and do not differ in their EC effects.

To try to disentangle the relationship between memory and EC, an item-based analysis was done following Pleyers et al. (2007). This analysis clearly showed that EC and memory are connected, since items with correct source memory elicited EC effects, but items with incorrect source memory elicited reverse EC effects. Nevertheless, based on an intense debate in the literature (Gast, Gawronski, et al., 2012; Gawronski & Walther, 2012; Hutter et al., 2012), the causal links between memory and EC remain unknown.

Experiment 5.3. Neural correlates of evaluative conditioning in younger and older adults

Introduction

The experiments described in Chapters 4 and 5 show that the procedure used in this thesis elicits robust EC effects. Moreover, experiments 5.1 and 5.2 show that the EC effects do not differ between younger and older adults. That is, the ability to attribute positive emotions to neutral information seems to be preserved in ageing. In relation to memory, experiment 4.2 revealed no differences in performance between valences, but experiment 5.1 showed an increase in performance for the words used in positive sentences. The current experiment looked at the relationship between memory and EC with the aid of neuroimaging. Dm and old/new ERP effects were contrasted according to whether younger and older participants attributed positive emotions to neutral words.

Most studies on EC use memory tasks as a proxy to arbitrate between the long-lasting debate on whether EC depends on contingency awareness during conditioning (Stahl & Unkelbach, 2009), as detailed in Chapter 1. However, this methodology cannot differentiate between mechanisms taking place during encoding and during retrieval. In other words, if EC and memory interact, it is unknown whether this relationship happens during encoding or retrieval (Gawronski & Walther, 2012). The use of neuroimaging techniques may help with this question, since it allows the analysis of brain responses to stimuli during different moments of the mnemonic process. Some studies have, in fact, investigated ERPs during recognition of neutral items encoded in emotional contexts. These studies found that early cortical activation depends on the valence previously paired with that item, but the typical old/new effects do not differ between valences (Fritsch & Kuchinke, 2013; Jaeger & Rugg, 2012; Kuchinke et al., 2015; Smith, Dolan, et al., 2004). It seems that only one study has looked at the combination of Dm effects and old/new effects during EC (Martinez-Galindo & Cansino, 2015, 2017). These authors found that neutral faces paired with positive financial outcomes were better remembered than the ones paired with negative or neutral outcomes. The faces paired with positive outcomes also elicited stronger Dm and old/new effects than faces in the other conditions, suggesting that EC with positive valence increases memory performance and memory-related cortical activation during encoding and retrieval. However, what the authors of that study call parietal old/new effect was found irrespective of hemisphere, so it is unclear whether it truly reflects the recollection-related old/new effect.

Therefore, the aim of the current study was to investigate the cortical activity that underlies EC in ageing and its relationship with episodic memory. Based on Chapter 3, it was expected that age-related differences would be seen during retrieval but not during encoding, and emotion-related differences during encoding and not during retrieval. This prediction is also in line with results showing no modulation of the typical old/new effects by the emotional context in which an item was encoded (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015; Smith, Dolan, et al., 2004) and by studies showing that emotional items elicit larger Dm effects than neutral items (e.g. Yick et al., 2015).

Methods

As explained at the beginning of this chapter, experiments 5.1 and 5.3 derive from the same data set. The behavioural data were presented and discussed in experiment 5.1 and the ERP data are presented below. Information about participants, materials and procedure can be found in the methods section of experiment 5.1. The information about EEG recording and ERP analyses will be detailed next.

EEG measures

EEG was recorded during the encoding and the retrieval phases of this experiment (the general EEG acquisition and processing details are outlined in Chapter 2). ERPs were calculated for each participant and electrode site according to the experimental condition and recognition memory judgement given to each image. Thus, in the study phase, each ERP epoch was classified as neutral/positive and as source correct/source incorrect/source unsure/miss. ERPs were analysed separately for prestimulus activity (after cue onset) and post-stimulus activity (after picture onset) (Otten et al., 2006). Items presented only in the test phase were classified as new and as source false alarm/item false alarm/correct rejection. Only post-stimulus activity was analysed in the test phase.

Twenty-four younger adults and 23 older adults were kept for the retrieval ERP analyses because they had the minimum number of artefact-free trials. 23 in each age group were kept for the encoding analyses. Encoding data were analysed by comparing source correct trials and source miss trials (calculated as a combination of source incorrect and source unsure trials). For the retrieval phase, the analyses were between source correct trials and correct rejections.

For the encoding phase, source correct trials were defined as old items given a correct source judgment. Source miss trials were defined as old items classified as source incorrect or source unsure. The number of trials used in the ERP analyses can be seen in Table 5.3.1.

Table 5.3.1. Mean trial numbers used in the ERP analyses.

			Younger adults	Older adults
Encoding, prestimulus	Positive	Source Correct	41.2 (9.0)	34.4 (10.0)
		Source Miss	17.9 (5.8)	23.3 (9.4)
	Neural	Source Correct	34.2 (14.4)	30.6 (13.9)
		Source Miss	22.3 (8.2)	28.8 (12.7)
Encoding, post-stimulus	Positive	Source Correct	41.6 (9.0)	35.5 (10.2)
		Source Miss	18.0 (5.8)	23.4 (9.0)
	Neural	Source Correct	34.5 (14.6)	30.8 (13.7)
		Source Miss	22.5 (8.3)	29.0 (12.4)
Retrieval	Positive	Source Correct	42.3 (8.5)	30.6 (13.3)
	Neutral	Source Correct	37.3 (12.8)	29.9 (13.6)
	New	Correct Correct	40.5 (7.5)	37.1 (9.7)

The numbers in parentheses are standard deviations.

ERP analyses

ERP waveforms were contrasted according to the valence of the sentence (neutral/positive), the accuracy of the decision to the word during the memory test (source correct/source miss for encoding data, and source correct/correct rejections for retrieval data), and the interaction of these factors. For the encoding data, the continuous record was divided into time windows to assess differences across time. The time windows for prestimulus and post-stimulus activity were the same as the ones used in experiment 3.2. Accordingly, encoding-related activity was assessed between 300-700, 700-1100 and 1100-1500ms after cue onset and between 200-600, 600-1100 and 1100-1900ms after word onset. The scalp partition was also the same as the one used previously in this thesis (Figure 2.2). Encoding data were submitted to a mixed-model ANOVA with within-subjects factors of location (frontal/posterior), hemisphere (left/right), time window, subsequent memory (source correct/source miss), emotional valence (neutral/positive), and the between-factor of age group (younger/older). For the retrieval data, the chosen time windows and electrode sites were the same as used in experiments 3.1 and 3.2, 300-500ms over frontal scalp sites, 500-800ms over left parietal sites, and 800-1200ms over right frontal sites. Analysis of retrieval data was done specifically for each time window and scalp region and had only source correct/correct rejection, emotional valence and age group as factors for the ANOVA.

Results

Prestimulus Dm effects

Subsequent-memory effects for source information before word onset did not seem to be affected by the valence of the sentence (Figure 5.3.1). In fact, differences between the ERP activity elicited by later source-correct words and later source-miss words seemed very small, with more negative-going activity over posterior sites for later source correct words. A mixed-model ANOVA was run with age as a between-subject factor, and time window, emotional valence, hemisphere, location and memory response (source correct/source miss) as within-subject factors.

Two interactions came out significant. One between emotional valence, memory and hemisphere ($F(1,45) = 13.340$, $p = .001$, $\eta^2_p = .229$). This interaction was analysed by looking at each valence individually. Both valences showed an interaction between memory and hemisphere [positive: ($F(1,45) = 6.633$, $p = .013$, $\eta^2_p = .129$); neutral ($F(1,45) = 8.227$, $p = .006$, $\eta^2_p = .155$]. However, follow-up analyses for each hemisphere failed to find significant effects of memory ($p > .054$).

The second interaction to emerge from the initial ANOVA was between age, time window, emotional valence and memory ($F(1.9,85.8) = 4.984$, $p = .010$, $\eta^2_p = .100$). When this interaction is decomposed by looking at each age group, no significance is found (YA: $p > .094$; OA: $p > .482$). Similarly, when looking at each time window, no significant effects or interaction with memory are found ($p > .166$).

In experiments 3.1 and 3.2, prestimulus activity was maximal over posterior sites. Thus, in the current study, a new analysis was conducted only on posterior electrodes. Similar to the earlier results, this ANOVA revealed a significant interaction between valence, memory and hemisphere $F(1,45) = 12.161$, $p = .001$, $\eta^2_p = .213$). Looking at each emotional valence individually, both positive and neutral items revealed an interaction between memory and hemisphere [positive: ($F(1,45) = 5.311$, $p = .026$, $\eta^2_p = .106$); neutral ($F(1,45) = 8.822$, $p = .005$, $\eta^2_p = .165$]. However, neutral items showed no significant effects of memory on either side ($p > .464$). Positive items showed no effects on the left side ($p = .916$) and a negative-going effect on the right side that just failed significance ($p = .059$). No effects of age were found ($p > .271$).

In summary, no statistically significant prestimulus Dm effects were found. It is possible that participants simply did not prepare differentially for creating neutral and positive sentences. So, an additional set of analyses was conducted to test whether the emotional valence of a sentence influenced cortical activity irrespective of later memory. To do that, ERPs aggregated across all positive trials were contrasted with the ERPs aggregated across all neutral trials, regardless of the judgment given by participants during the memory task (Smith, Dolan, et al., 2004). The same partition and time windows were used. However, analyses did not reveal significant results related to valence ($p > .064$). In conclusion, ERPs did not differentiate before word onset as a function of the valence of the sentence that had to be made.

Post-stimulus Dm effects

Regarding post-stimulus encoding-related activity, differences between later source-correct and later source-miss words also seemed very small (Figure 5.3.2). Positive trials elicited slightly more positive-going activity at frontal sites for YA, whereas neutral trials elicited more negative-going activity at frontal sites of OA. To test the statistical significance of these effects, the same ANOVA factors used for prestimulus analyses were used here, with the exception of the chosen time windows.

Two interactions were found. One was between time window, emotional valence and memory ($F(1.9,83.7) = 6.628$, $p = .003$, $\eta^2_p = .128$), and the other was between emotional valence, memory and hemisphere ($F(1,45) = 5.793$, $p = .020$, $\eta^2_p = .114$). These interactions were analysed by looking at each emotional valence individually. Neutral items revealed an interaction between memory and hemisphere ($F(1,45) = 6.328$, $p = .016$, $\eta^2_p = .123$). The decomposition of this interaction revealed significant memory effects on the left hemisphere ($F(1,45) = 4.371$, $p = .042$, $\eta^2_p = .089$), but not on the right hemisphere ($p = .813$). Positive items revealed an interaction between memory and time window ($F(2,90) = 3.928$, $p = .023$, $\eta^2_p = .080$). However, the effects of memory in each time window were not significant ($p > .231$). No age effects were found ($p > .061$).

In summary, emotion had a general influence on post-stimulus activity, with neutral items eliciting negative-going Dm effects on the left electrode sites.

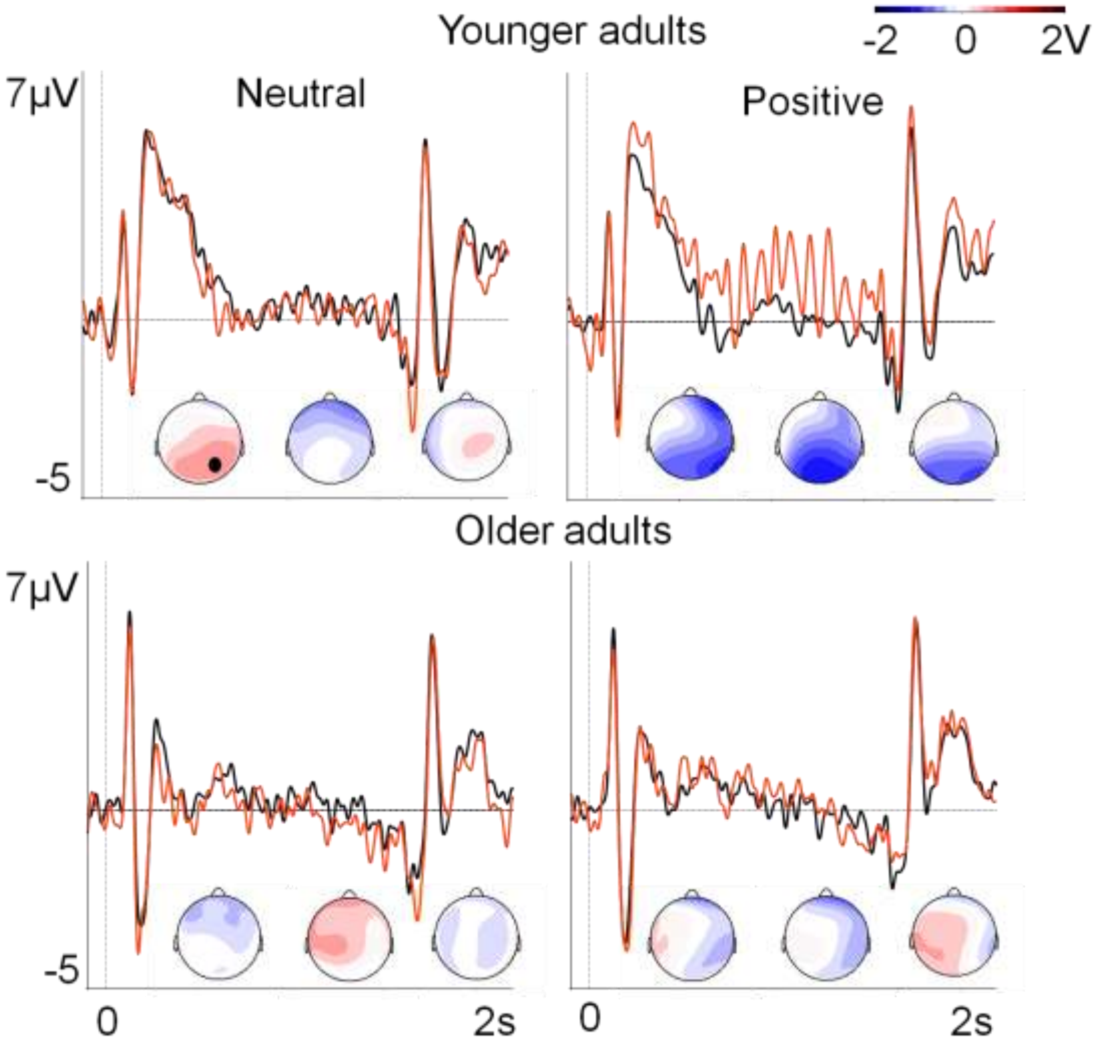

Figure 5.3.1. Subsequent memory effects before word presentation in younger and older adults.

The grand-averaged ERPs represent a right-posterior electrode site (black dot). Scalp maps display the subtraction of the trials later given a source miss judgment (coloured lines) from the ones later given a source correct judgment (black lines). These maps show the scalp distribution of the effects in the 300-700 (left), 700-1100 (middle) and 1100-1500ms (right) interval. The dotted lines represent cue onset.

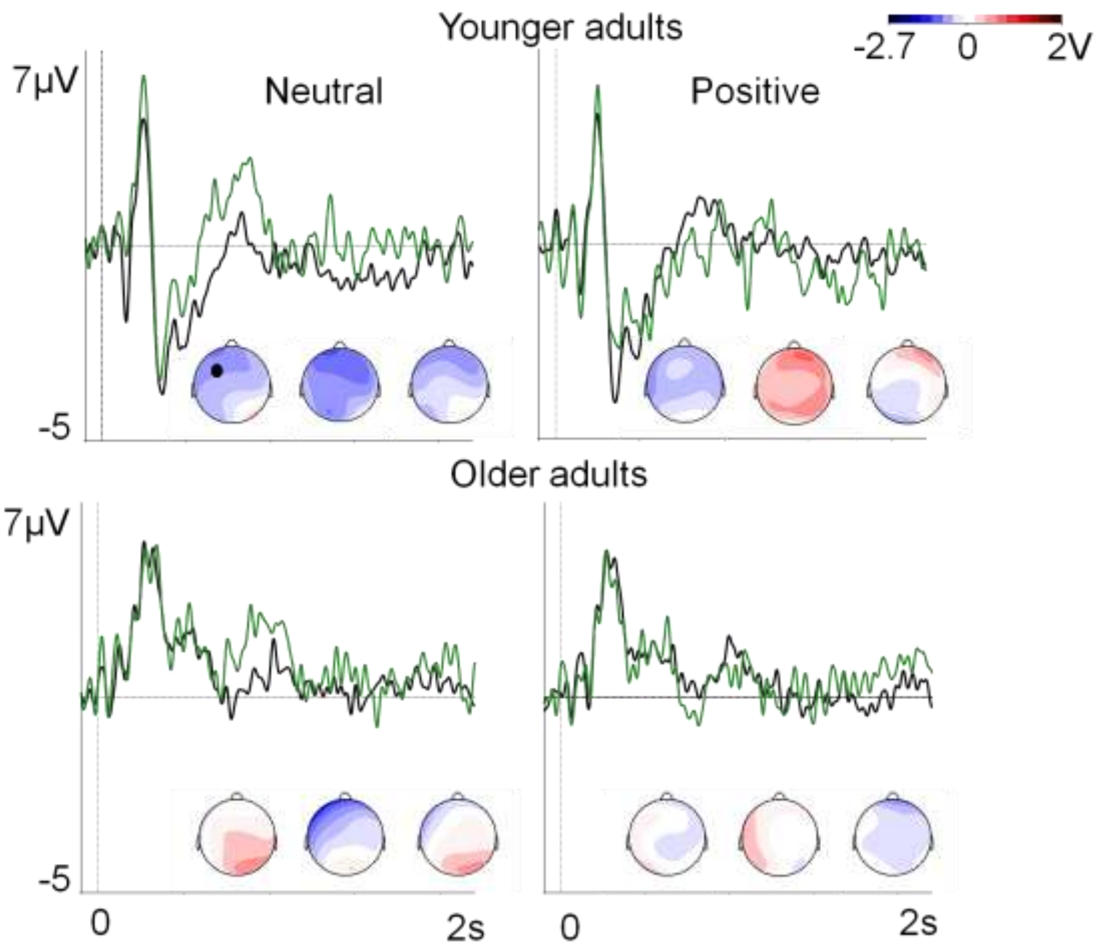

Figure 5.3.2. Subsequent memory effects after word presentation in younger and older adults.

The grand-averaged ERPs represent a left-anterior electrode site (black dot). Scalp maps display the subtraction of the trials later given a miss source judgment (coloured lines) from the ones later given a source correct judgment (black lines). These maps show the scalp distribution of the effects in the 200-600 (left), 600-1100 (middle), 1100-1900ms (right) interval, also represented by the grey rectangles. The dotted lines represent word onset.

Old/new effects

As explained in the methods section, retrieval-related brain activity was analysed with mixed-model ANOVAs each time window and area where the mid-frontal, left-parietal, and right-frontal effects were largest. The 300-500ms time window (Figure 5.3.3) revealed the presence of mid-frontal effect ($F(1,45) = 7.870$, $p = .007$, $\eta^2_p = .149$), with no effects of age or valence ($p > .380$). The 500-800ms time window (Figure 5.3.4) revealed an overall left-parietal effect ($F(1,45) = 10.909$, $p = .002$, $\eta^2_p = .195$), not influenced by valence or age ($p > .357$). The 800-1200ms time window did not show a right-frontal old/new effect ($p > .138$).

A different type of activity seemed to be present in the 800-1200ms time window rather than the typically observed right-frontal effect. This activity consisted of a strong posterior negativity present in YA and in positive trials (Figure 5.3.5). This pattern of a late negativity in posterior sites during retrieval has been seen in other studies and receives the name of “late posterior negativity” (LPN). In a review paper, Johansson and Mecklinger (2003) suggest that LPN effects reflect the mental reconstruction of a previous episode. Thus, a new analysis in the current study was conducted by selecting a set of posterior electrodes (see Figure 2.2) previously used to study LPN effects in ageing (J. Li et al., 2004; Newsome et al., 2012). The analysis revealed that LPN effects were present and significantly influenced by emotional valence ($F(1,45) = 9.772$, $p = .003$, $\eta^2_p = .179$). Follow-up analyses for each emotional valence showed that this old/new effect was present for neutral ($F(1,45) = 4.695$, $p = .036$, $\eta^2_p = .095$) and for positive items ($F(1,45) = 17.168$, $p < .001$, $\eta^2_p = .276$). However, a direct comparison between the strength of the effects in the two valences revealed that it was significantly larger for positive trials ($F(1,45) = 9.772$, $p = .003$, $\eta^2_p = .179$). No effects of age were found ($p = .411$).

Similarly to the previous chapter, each age group was looked at separately. The mid-frontal effect was present only in OA ($F(1,22) = 4.481$, $p = .046$, $\eta^2_p = .169$; YA $p = .069$). The left-parietal effect was present only in YA ($F(1,23) = 8.936$, $p = .007$, $\eta^2_p = .280$; OA $p = .132$). The LPN effect was present for positive trials in YA ($F(1,23) = 15.494$, $p = .001$, $\eta^2_p = .280$; OA $p = .403$) and in OA ($F(1,22) = 4.478$, $p = .046$, $\eta^2_p = .280$; OA $p = .169$). For neutral trials, the effect approached significance in YA ($p = .056$), but not it OA ($p =.310$).

In summary, when contrasting source correct old items with correctly recognised new items, mid-frontal and left-parietal effects were present regardless of age or emotional valence. However, no right-frontal effects were found. Additionally, LPN effects were significantly larger for words used in positive sentences.

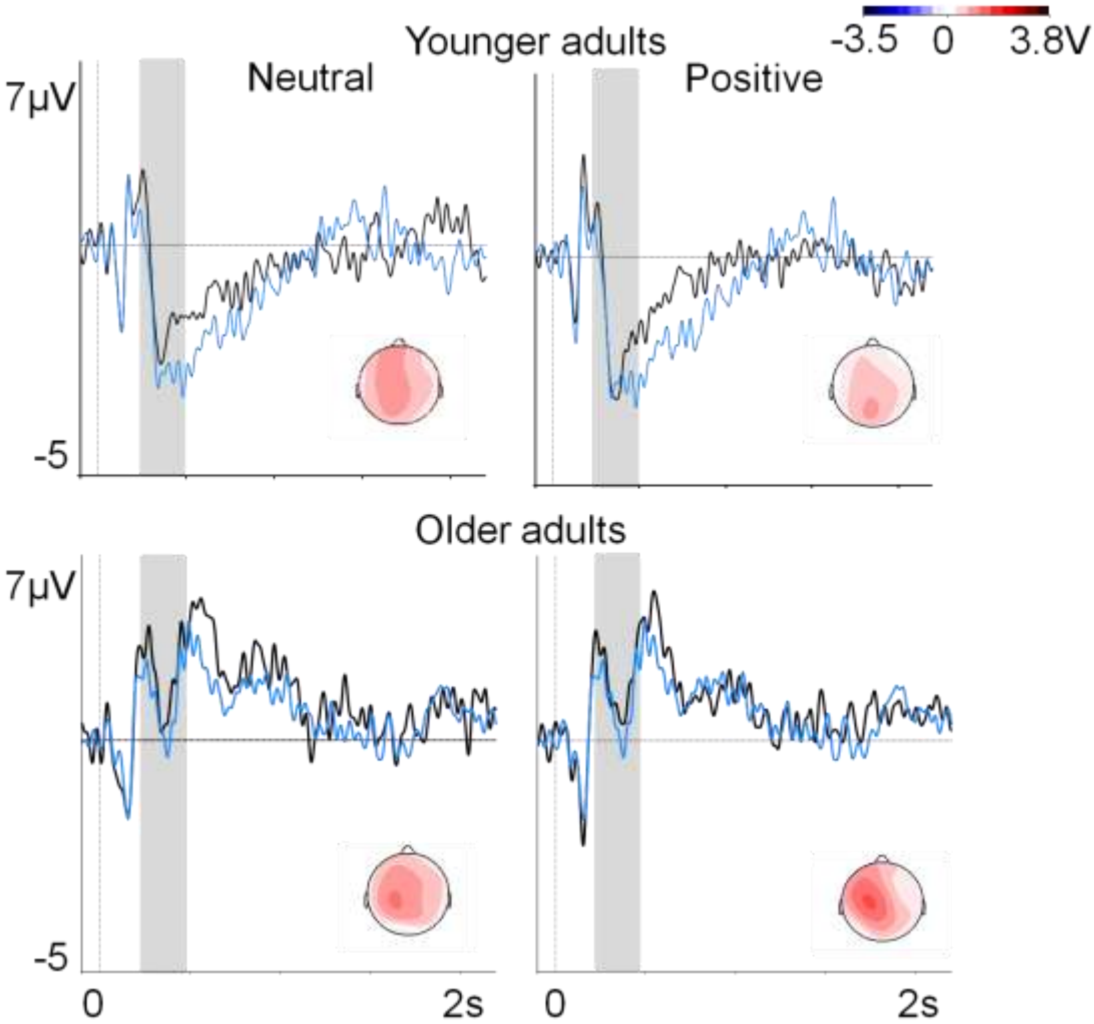

Figure 5.3.3. Mid-frontal old/new effects in younger and older adults.

The grand-averaged ERPs represent a mid-frontal electrode site (black dot). Scalp maps display the subtraction of the trials correctly rejected (coloured lines) from the ones given a correct source judgment (black lines). These maps show the scalp distribution of the effects in the 300-500ms interval, also represented by the grey rectangles. The dotted lines represent word onset.

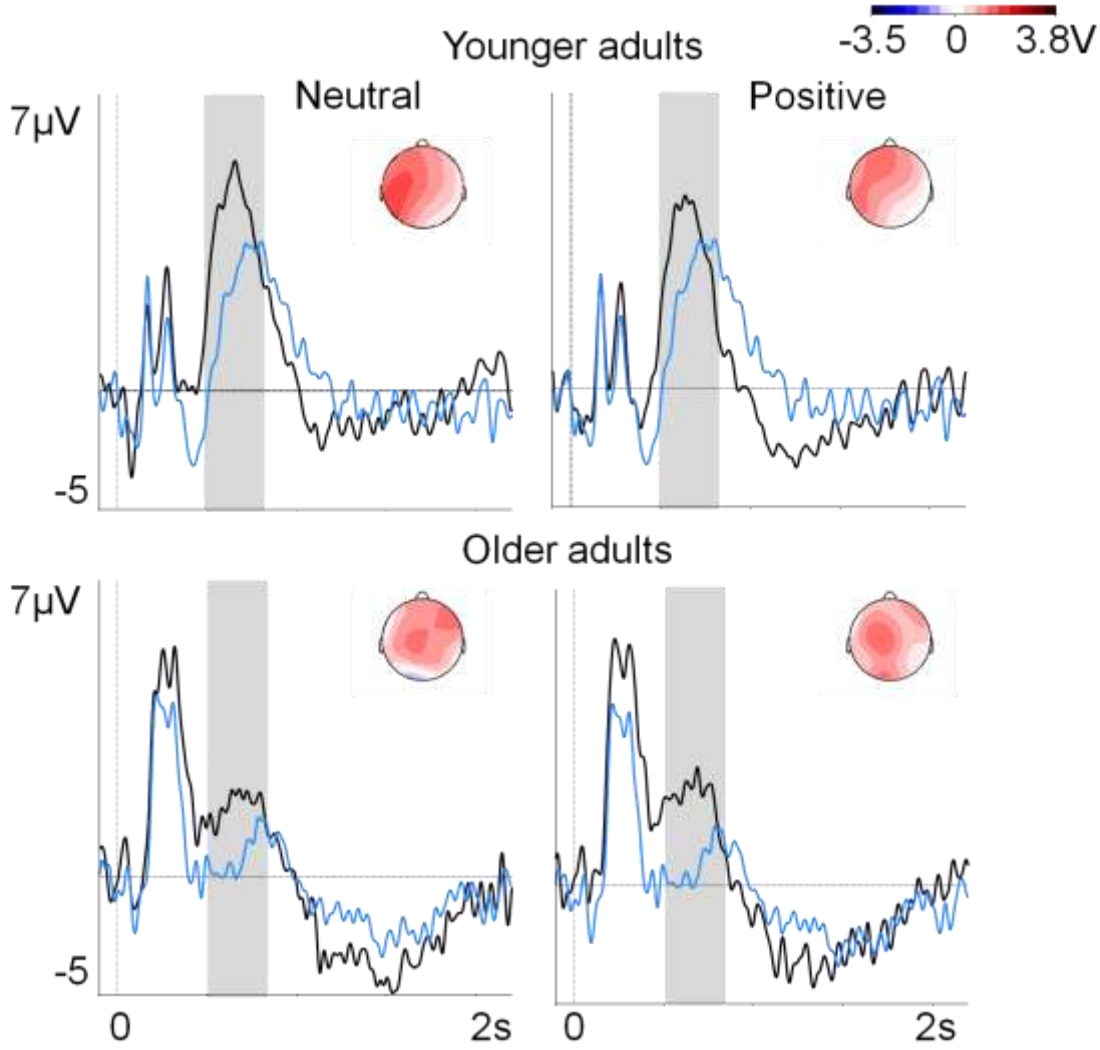

Figure 5.3.4. Left-parietal old/new effects in younger and older adults.

The grand-averaged ERPs represent a left-parietal electrode site (black dot). Scalp maps display the subtraction of the trials correctly rejected (coloured lines) from the ones given a correct source judgment (black lines). These maps show the scalp distribution of the effects in the 500-800ms interval, also represented by the grey rectangles. The dotted lines represent word onset.

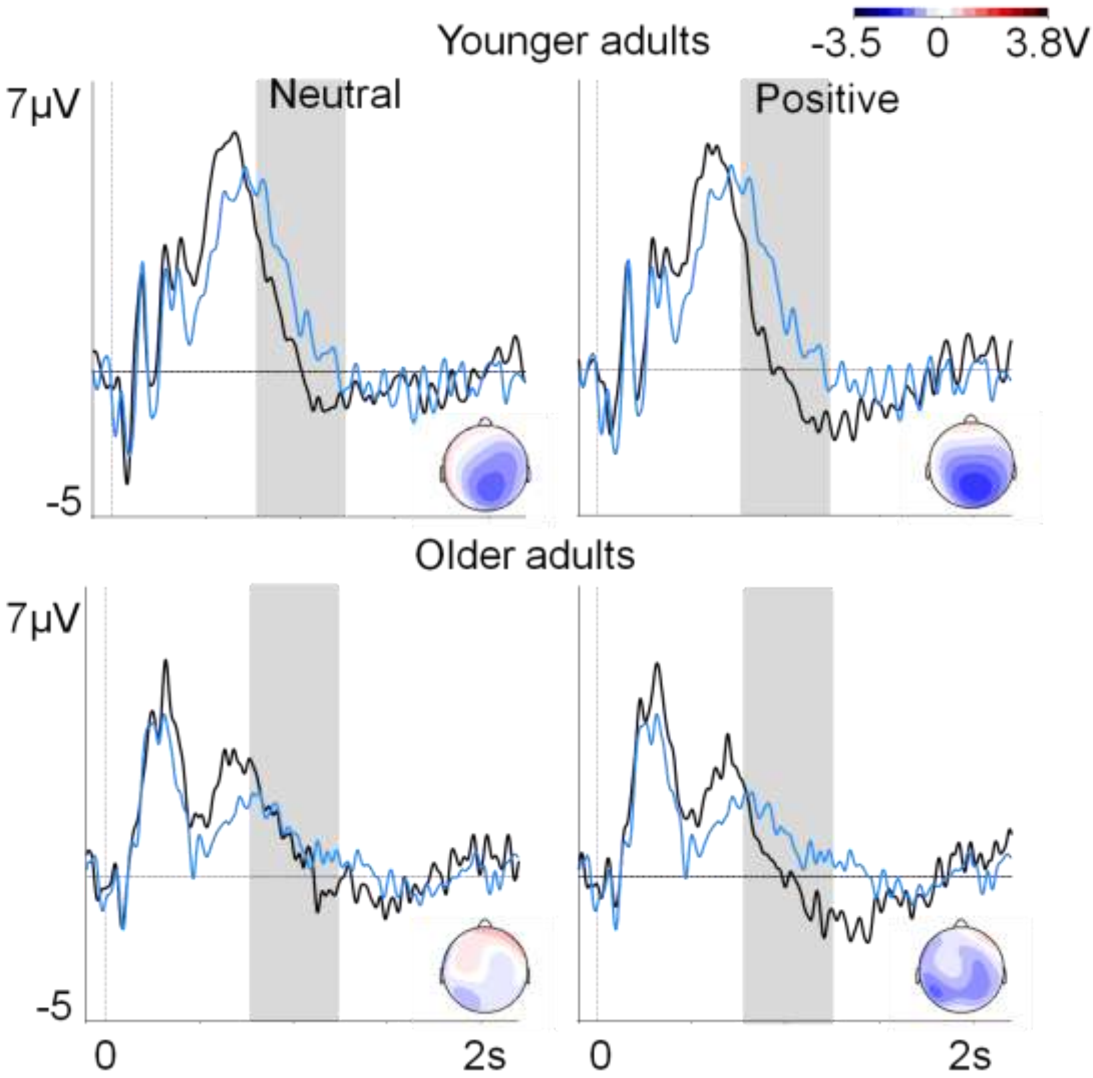

Figure 5.3.5. Old/new effects suggestive of the late posterior negativity in younger and older adults.

The grand-averaged ERPs represent a mid-posterior electrode site (black dot). Scalp maps display the subtraction of the trials correctly rejected (coloured lines) from the ones given a correct source judgment (black lines). These maps show the scalp distribution of the effects in the 800-1200ms interval, also represented by the grey rectangles. The dotted lines represent word onset.

Discussion

The current study investigated the neural correlates of the interaction between memory and EC in ageing. Dm effects were analysed whilst participants attributed positive emotions to neutral information. Old/new effects were also compared according to previous emotion attribution. The results showed that even without the presence of intrinsically emotional stimuli, brain activity differed between words used to create positive sentences from the ones used to create neutral sentences during encoding and retrieval. Additionally, no statistical age-related differences were found in the ERP data.

Encoding-related activity

Prestimulus activity was analysed by investigating the general preparation for each emotional valence and also Dm effects. None of the analyses revealed significant effects. This suggests that participants did not use anticipatory mechanisms before creating the sentences. It is possible that this was not necessary because the exposure duration time of the word was long, as suggested in experiment 3.2 of this thesis. However, it is also possible that anticipatory mechanisms are only present before decision-making. With only one exception (Gruber et al., 2014) , all the other previous studies about prestimulus Dm effects have asked participants to make a decision or use specific strategies with the upcoming item during encoding (Galli et al., 2011,2012,2013; Galli, Choy, & Otten, 2012; Gruber & Otten, 2010; Gruber et al., 2013; Otten et al., 2006,2010; Padovani et al., 2011; Yoo et al., 2012). Thus, it is possible that prestimulus brain activity is related to decision-making. It is interesting to note that, when looking at posterior sites only, activity on the right electrode sites showed a Dm effect that reached $p = .059$. This scalp distribution is similar to the one seen in the previous chapter of this thesis and in the other two studies conducted with emotional information (Galli et al., 2011,2012). The possibility that prestimulus activity is related to decision-making should be analysed in a future study in which conditions that do and do not require a decision are compared.

Post-stimulus activity showed a negative-going Dm effect for neutral trials, which was not influenced by ageing. It is not clear why positive trials did not elicit significant Dm effects. A previous study showed that emotional items elicit larger positive-going Dm effects than neutral items (Yick et al., 2015). However, the emotional stimuli of this previous study were negative images, whereas the current study used mentally created positive sentences. Thus, it is possible that only negative items elicit a larger positive-going Dm effect. Another possibility is that this effect is only present for visual images, which was the case in Yick et al. (2015) and in experiment 3.1 of this thesis. Thus, the current results suggest no special Dm effect when participants imagine positive sentences, but more studies are needed.

Neutral trials elicited a negative-going Dm effect over the left hemisphere. It is possible that this activity reflects the use of a more object-based perceptual processing strategy by participants, similar to the findings of experiment 3.1. This idea is supported by data on response times. Response times in the current study showed that participants took longer to complete the positive sentences. It is not known whether they took longer to begin the sentence or if the sentences were themselves longer. In any case, the faster reaction time for neutral sentences raises the possibility that their encoding was shallower than that of positive trials. Shallow encoding has been shown to elicit negative-going Dm effects in a previous study (Otten & Rugg, 2001), so it may have happened in the current investigation as well.

Another possibility comes from a study by Schott, Richardson-Klavehn, Heinze, and Duzel (2002), who compared Dm effects for implicit and explicit memories. The authors presented participants with lists of words. Later, a stem-cued test was conducted, in which participants should complete a half-formed word and indicate if they remembered that word from the study phase or not. The authors compared encoding-related activity between words that were used in the stem-cue task and explicitly remembered by the participants with the ones used in the stem-cue task but not explicitly remembered. The results showed that the implicitly remembered words elicited a more negative-going Dm effect at central-parietal sites than the explicitly remembered words. This was interpreted by Schott et al. (2002) as evidence for the neurophysiological dissociation between the two types of memory. In the current study, all the words were neutral. Therefore, it is reasonable to speculate that the creation of neutral sentences brought up implicit associations between the sentence and the word to a higher degree than the creation of positive sentences. This suggestion is in line with a behavioural study that showed that EC effects depend on how many previous associations the neutral stimulus has before the conditioning procedure (Ruys & Stapel, 2009). Using implicit associations to explain the current ERP encoding data is tentative and will need to be supported by future studies that include an implicit memory task in addition to the explicit one used here.

Here, it is relevant to discuss the retrieval task used in this experiment. A source memory task was chosen to ensure comparisons between trials in which participants specifically remembered or forgot the emotional valence of the sentence. The use of the remember/know procedure, as done in Chapter 3, would have allowed more freedom for participants to retrieve any sort of contextual information from encoding. Thus, if the creation of neutral sentences really did bring up more implicit associations than the creation of positive sentences, as discussed in the previous paragraph, a remember/know task may have been able to reveal stronger ERP effects. Thus, future studies may try to repeat the encoding phase of the current experiment with a new memory task, in which participants are encouraged to retrieve all types of associations between the word and the sentence.

Retrieval-related activity

Mid-frontal and left-parietal effects were found in the current study irrespective of valence and age. An unexpected but interesting result was the presence of a negative-going old/new effect in the late time window maximal at parietal sites, stronger for positive trials.

This negative-going activity has been seen in other source memory studies, such as the one by Cycowicz, Friedman, and Snodgrass (2001). In that study, the authors compared old/new effects during retrieval of the colour by which the items had been surrounded during retrieval. The authors found a left-parietal effect, no right-frontal effect and the presence of a negative-going activity at parietal sites beginning around 800ms after item onset, which is markedly similar to the findings of the current study. Because in that study, the source to be retrieved was purely visual information (line colour), the authors concluded that the negative activity was related to the search of visual information from the previous episode, or to the reinstatement of that initial image. A similar negative-going activity was found by Johansson, Stenberg, Lindgren, and Rosén (2002). In that study, participants saw words representing objects paired with images of those objects or with an empty frame. In the latter condition, the image of the object should be imagined. Old/new effects during the source memory task that followed showed a negative-going activity beginning at 1000ms on posterior sites. Although the effect was larger for the images, it was also statistically present for the imagined items. The authors could not suggest a functional role for the effect. The proposal by Cycowicz et al. (2001) that the negative-going activity reflects the search for visual information has been subsequently used in the ageing literature to explain different results, as detailed next.

In the ageing literature, this negative activation has been found but in mixed forms. J. Li et al. (2004) used a source memory task with images and found that older adults, but not younger adults, showed a sustained negativity maximal on the left hemisphere. The authors used Cycowicz et al. (2001)'s proposal that the negative activity reflects search for visual information to suggest that older adults relied on a more perceptual-based recovery of the encoding information. In contrast, Wegesin et al. (2002) found that this negative-going old/new effect was central in distribution for older adults, but occipital for younger adults. The authors also combined their data with Cycowicz et al. (2001)'s proposal to suggest that the retrieval process used by younger and older adults is qualitatively different. However, the results of the current study showed no differences between younger and older adults and, thus, are in line with those from Newsome et al. (2012), who found the negative-going old/new effect for both age groups. Interestingly, in that study, the negative-going activity was only found for negative and not for neutral or positive images. In the current study, the negativity was stronger for the positive trials, although, of course, it is not possible to infer what the pattern would be for negative sentences. In the Newsome et al. (2012) study, negative valence impaired recognition memory for the images, and the authors suggest that the larger negative-going old/new effect enhanced the search for visual information that was not relevant to the task, impairing the retrieval of the relevant ones. These data do not seem to be compatible with the ones from the current study, since here the negative activity was stronger for the positive trials, which also showed stronger memory. Nevertheless, the two sets of data indicate that the posterior negativity found in source memory tasks may be modulated by emotion, although the exact mechanisms are unclear. A future study could use the protocol developed in this thesis and test negative valence as well.

In a review paper, Johansson and Mecklinger (2003) proposed a functional role for the posterior negative-going old/new effect. According to the authors, the amount of data accumulated on this effect allows the conclusion that it reflects a mnemonic process different from what is captured by the left-parietal effect. While the latter relates to the retrieval of contextual information triggered by the item, the LPN reflects the combination of such information with internally generated aspects that are useful for the current task. In other words, the previous episode is internally re-experienced in an attempt to retrieve additional information relevant for a given decision. The process of reliving a previous episode in one's mind seems similar to the classic definition of mental time travel by Tulving (1993). In that definition, mental time travel happens when "a person can transport at will into the personal past, as well as into the future" (p. 67). More recently, Suddendorf and Corballis (2007) proposed that mental time travel is not a restricted cognitive mechanism, but a combination of different processes. Some of those processes include imagination, semantic memory, decision-making, inhibition and language. Thus, it is possible that LPN effects are related to part of these processes, likely imagination, helping participants to mentally re-experience past events and leading to more accurate memory.

The proposal that the LPN is involved in internally re-experiencing an episode is supported by different experimental studies, such as the one by Gonsalves and Paller

(2000). These authors used a similar task as the one used by Johansson et al. (2002), with words followed by either images or empty frames, when participants should imagine the object. The results showed that only words from the imagining trials elicited an occipitally focused negativity when compared to new words. Other studies using similar methodology have also found a stronger LPN during retrieval of imagined than perceived items (Rosburg, Mecklinger, & Johansson, 2011a, 2011b). It is possible that the LPN in those cases was related to filling in visual information that was not available from the original image in order to provide an accurate old/new response (Johansson & Mecklinger, 2003; Mecklinger, Rosburg, & Johansson, 2016). In accordance with that proposal, Herron (2007) showed that an increase in task fluency was followed by a decrease in LPN amplitude in the 600-1200ms time window. The author concluded that with more practice, more source information is available, and less mental reconstruction is involved during retrieval. The role of the LPN in mentally reconstructing an episode has also been included in Kent and Lamberts (2008)`s proposal of how brain simulation influences encoding-retrieval relationships.

Returning to the current study, it is possible to speculate that the larger LPN seen for positive trials was related to this internal search for contextual information. The fact that the effect was larger for the positive trials, although the neutral ones had the exact same visual information presented during encoding is very interesting. It may be that the positive emotion attribution during encoding enhanced the imagery level of the sentence. That is, attributing positive emotions may have made the sentence easier to be visualised. This enhanced visualization may later have been used during the retrieval task to provide more accurate source responses than the neutral sentences. In conclusion, it is possible that this is an underlying mechanism by which evaluative conditioning relates to memory. Although tentative, this proposal is compatible with the behavioural findings from De Houwer (2006), Gast and De Houwer (2013), and Baeyens, Heremans, Eelen, and Crombez (1993), explained earlier, who found links between imagery and EC effects. Similarly, Fulcher et al. (2001) showed that vividness for positive mental images is higher than for negative or neutral images. Imagery tests, such as the Vividness of Visual Imagery Questionnaire (D. Marks, 1973) or the Object-Spatial Imagery Questionnaire (Blajenkova, Kozhevnikov, & Motes, 2006), should be used in future studies to investigate how individual differences affect EC, memory and its brain correlates. It is important to note that Gonsalves and Paller (2000), and Rosburg et al. (2011a,2011b) found larger LPNs and worse memory for the imagined condition compared to the perceived condition whereas the current study found larger LPN and better memory for the positive trials compared to the neutral trials. These distinct behavioural findings are not contradictory because, in the current study, there was no perceived condition, i.e. the neutral trials were also imagined trials. It is not possible to say, from the current study, if memory for sentences written on the screen would be better or worse than the ones imagined by participants, and a future study should probably test that.

Conclusion

The current study investigated encoding and retrieval brain activity during EC in younger and older adults. Participants did not seem to prepare for the upcoming trials. After word onset, neutral trials elicited a significant post-stimulus Dm effect that may have been connected to shallow encoding or to implicit associations brought to mind by the neutrality of those words. Interestingly, during retrieval, a posterior negative-going activity was found to be larger for positive trials compared to neutral trials. This activity resembles the LPN effects linked to imagery and mental reconstruction of a prior episode. It is possible that this is a brain mechanism by which EC and memory are related.

Chapter 6: General discussion

The overarching interest of this thesis was the interaction between memory, emotion and ageing via the use of behavioural and neurophysiological methods. This thesis also investigated emotion attribution and evaluative conditioning to understand how neutral information becomes emotional and how this is encoded and retrieved from memory. The current chapter will begin by summarizing the findings from the seven experiments according to their research questions. The chapter will end by drawing scientific and applied implications of the findings and by proposing ideas for future research in the field of cognitive ageing and emotional memory.

Summary of findings

Effects of emotion on memory brain correlates in younger and older adults (Chapter 3)

In two experiments, episodic memory for emotional images was assessed behaviourally and with the use of ERPs. The main question was whether different emotional valences would influence performance and memory-related brain activity at three time points: before and after stimulus presentation during encoding, and after probe onset during retrieval. Specifically, experiment 3.1 asked whether these effects would differ between younger and older adults. Experiment 3.2 asked whether they would be influenced when stimulus duration during encoding was manipulated.

In experiment 3.1, younger and older participants incidentally encoded neutral, negative and positive images preceded by facial cues indicating the valence of the upcoming stimulus. A recognition memory task followed (Tulving, 1985). ERPs were calculated in response to cues and images during encoding and to images during retrieval. This experiment was designed to fill in two gaps in the literature. The first one concerns whether the effects of ageing on memory are more prominent during encoding or during retrieval. The second one is how prestimulus encoding-related activity materialises in older adults. In terms of memory performance, overall accuracy did not differ between the two age groups, although younger adults were better with negative images (cf. Baumeister et al., 2001; Rozin & Royzman, 2001), and older adults were more accurate with neutral images, possibly due to their lesser visual complexity (cf. McDonough et al., 2014). In terms of ERPs, the results were in line with Gutchess, Ieuji, et al. (2007), since younger adults showed the typical left-parietal effect usually connected to recollection (Curran, 2004), and older adults did not show even a hint of this effect.

The absence of the left parietal effect in high-performing OA is a novel finding, since previous literature reports smaller or absent left-parietal effects in older adults in the presence of lower performance in that age group (reviewed by Friedman, 2013). Since performance in experiment 3.1 did not differ between younger and older adults, it is possible that the ageing group used a different, maybe compensatory, brain mechanism to retrieve the stimuli (cf. Cabeza, 2002; Reuter-Lorenz & Cappell, 2008). However, even though the data strongly suggest the absence of the left-parietal effect in older adults, no age-related differences were found for the mid-frontal or the right-frontal old/new effects. From visual inspection, it seems that the right-frontal effect began earlier in older than in younger adults. This would suggest that older adults deploy this monitoring (Windmann et al., 2002) or decision-making (Hayama et al., 2008) mechanism to compensate for the lack of recollection. This possibility is purely speculative and would require a new study to look at it as a pre-experimental prediction.

As already mentioned, data from experiment 3.1 agree with Gutchess, Ieuji, et al. (2007) that ageing effects are more visible during retrieval. Despite no age-related effects on encoding, post-stimulus activity showed marked valence effects. Negative and positive images showed the expected positive-going Dm effects over fronto-centro scalp sites (Paller & Wagner, 2002). Interestingly, neutral images elicited an atypical posteriorly-distributed negativity that may be associated with using an object-based perceptual process (Otten & Rugg, 2001) to encode the less visually complex neutral images. To properly investigate this proposal, studies that match neutral and positive/negative images on their perceptual features or that use words as stimuli should be conducted.

The second gap in the literature addressed by experiment 3.1 was the presence of prestimulus encoding-related activity across the lifespan. The study of prestimulus activity in older adults could possibly add information to the different models that try to explain cognitive ageing (Reuter-Lorenz & Park, 2010). Galli et al. (2011) showed that younger adults only display preparatory activity before negative items, due to their evolutionary importance. Because of the well documented shift in emotional focus during the lifespan from negative to positive events (Carstensen & Mikels, 2005; Urry & Gross, 2010), it was predicted that older adults would show preparatory brain activity before positive items only. The results did not support the prediction, since a main Dm effect was found but it did not interact with valence or age. Because this is the first time that preparatory Dm effects are studied in older adults, and because it was a null finding, the results need to be taken with caution. Nevertheless, they suggest that preparatory brain activity is preserved in ageing, at least in high-performing older adults. Bollinger et al. (2011), although not measuring Dm effects, compared brain activity before items in trials where an informative cue was presented with the trials where an ambiguous cue was displayed. The older participants were separated into high and low performing groups based on the later memory task and only the first group showed significant activity in preparation for the upcoming item. Thus, it is possible that a preserved anticipatory mechanism helps older adults in memory tasks. Experiment 3.1 did not have enough participants to compare preparatory activity between high and low-performing older adults, but this can be achieved in a future study with a larger sample. If preparatory brain activity truly aids older adults with their memory, future studies should try to apply it to cognitive training.

An important feature to be mentioned about the results regarding prestimulus activity in experiment 3.1 is that the younger adults' data did not replicate Galli et al. (2011)'s study. A main positive-going Dm effect maximal over right-posterior scalp sites was found. This pattern strongly resembles the ones seen previously in studies regarding emotional preparation (Galli et al., 2011, 2012). However, differently from those studies, the current data did not interact with the valence of the stimulus. This discrepancy may have been caused by the longer stimulus duration during encoding in experiment 3.1. This idea comes from Zanto et al. (2011)'s ERP study showing that younger adults use preparatory cues when those cues indicate a quickly approaching target, but not when they indicate that a long time remains before the target is presented. Thus, it is possible that in Galli et al. (2011)'s study, the short duration of the stimulus prompted participants to prepare for an urgent decision when meaningful events such as negative stimuli were involved. On the other hand, the longer duration in experiment 3.1 may have made the task easier for participants and removed the necessity of preparation. This hypothesis was directly tested in experiment 3.2.

Experiment 3.2 followed on from experiment 3.1 and manipulated stimulus duration during encoding. For half the blocks, participants were informed that the images would be presented for 1s. For the other half, the images would be displayed for 2s. The prediction was that prestimulus Dm effects would be seen for negative images in the short condition only. That is precisely what happened. A right-posterior positivity was found, replicating the pattern seen in experiment 3.1 and the previous emotion literature (Galli et al., 2011, 2012). However, this activity was only significant before negative images in the short condition. An immediate implication of this result is that it helps to explain the discrepancies between findings from experiment 3.1 and Galli et al. (2011). The valence-related differences in prestimulus activity were probably not found in experiment 3.1 because the duration of the images was long enough to eliminate the need for specific preparation before negative images.

Nevertheless, the findings of experiment 3.2 have broader implications in explaining the functional role of anticipatory brain activity. According to Galli et al. (2013), prestimulus Dm effects are only significant when enough cognitive resources are available at the time. That is, when participants do a simultaneous secondary task, they lose the ability to prepare for the upcoming stimulus. In experiment 3.2, availability of cognitive resources was not manipulated, but the necessity of preparation was. When participants knew they would have enough time to make a decision in the long-duration condition, they did not prepare. Combining the two data sets, it is possible to propose that preparatory brain activity depends on the availability of cognitive resources but is only deployed when necessary for an accurate response. In other words, prestimulus activity seems to be an effortful but flexible mechanism (cf. Gruber & Otten, 2010). Future studies should, logically, investigate the effects of stimulus duration on positive events.

Another interesting finding from experiment 3.2 is the opposite effect that the interaction between valence and duration had on encoding and retrieval related activity. Post-stimulus Dm effects were found for the negative-short, negative-long, and neutral-long conditions, whereas the right-frontal effect was found for the negative-long and neutral-short conditions. Previous literature has shown that the right-frontal effect may reflect a post-monitoring retrieval mechanism for when information is shallowly encoded (Rugg et al., 2000), or it may also occur when an upcoming decision is needed (Hayama et al., 2008). Thus, in experiment 3.2, it seems like the right-frontal effect has both functions, since it was found for items that showed absence encoding-related activity, and for items that were more deeply encoded.

To sum up, experiment 3.1 investigated whether the effects of ageing were more pronounced during encoding or retrieval. The results showed that, although valence markedly influenced encoding, age-related differences were only present during retrieval. This result suggests that older adults are able to learn new information, but need compensatory mechanisms to retrieve it. This result also testifies to the importance of investigating encoding and retrieval in the same study (Kuo, Liu, & Chan, 2012). Experiment 3.2 showed that encoding and retrieval may compliment or compensate each other. With respect to prestimulus Dm effects, experiment 3.2 suggested that preparatory activity is an effortful and flexible mechanism that is only activated when necessary. Accordingly, its preservation in high-performing older adults in experiment 3.1 may be linked to them having enough cognitive resources to deploy it, which, in turn, supports memory.

Voluntary emotion attribution and evaluative conditioning (Chapter 4)

In two behavioural studies, the interaction between emotion attribution and memory was investigated from a naturalistic point of view. In other words, experiments 4.1 and 4.2 tested participants' spontaneous emotion attribution and its relationship with memory. Emotion attribution was operationalised via evaluative conditioning, which is the transfer of valence from one stimulus to another due to their pairing (Jones et al., 2010; Levey & Martin, 1975). Experiment 4.1 asked whether people have a natural tendency to attribute emotions to neutral information and if that tendency correlates with different personality traits. Experiment 4.2 asked if EC effects and memory performance would differ following forced and voluntary emotion attribution.

In experiment 4.1, participants answered the Big 5 Personality questionnaire (John et al., 1991; John et al., 2008) and were asked to write a short story (two to five lines) using neutral words (Warriner et al., 2013) given. No further instructions were provided to allow for participants' natural tendency of emotion attribution to emerge. The stories were rated in valence and arousal by another group of participants. The results showed that, although participants added negative emotions to the words, the stories were still within the neutral and mild arousal ranges. Additionally, a negative correlation was found between neuroticism and valence. That is, participants with a higher score on neuroticism attributed more negative emotions to neutral information.

Previous research has shown that people in long-lasting stressful situations tend to think of everyday events in a positive light (Folkman & Moskowitz, 2000). Here, the results showed that, under normal circumstances, participants slightly add negativity to neutral events. This tendency is stronger for people with high neuroticism scores, similarly to the findings by Fulcher et al. (2001)' using a probe detection task. In this thesis, the relationship between neuroticism and emotion attribution is instead seen in an explicit and voluntary task. Experiment 4.1 expands the individual differences literature by showing that personality traits influence not only emotion regulation (Carver et al., 1989; Ehring et al., 2008; Garnefski & Kraaij, 2006a), but also emotion attribution.

In experiment 4.2, a novel EC protocol was tested, in which the emotional stimuli are generated by the participants themselves. The experiment was divided into three phases. In the encoding phase, participants' task was to create sentences with each word presented. The words were all neutral (Warriner et al., 2013) and preceded by schematic facial cues (cf. Chapter 3) that indicated whether the next sentence should be neutral or positive, or by an exclamation mark. In this latter condition, participants were free to decide whether to create a neutral or positive sentence. In the retrieval phase, participants saw those words again, mixed with new words and made source memory judgments for each. In the likeability phase, participants judged the old words according to how much they liked or disliked each of them. The presence of EC effects was measured by the difference in ratings between words used in positive sentences and words used in neutral sentences (De Houwer, 2007).

A crucial finding of experiment 4.2 was the clear presence of EC effects. That is, neutral words used in positive sentences became more liked than neutral words used in neutral sentences. This finding is important considering the novelty of the procedure used here in comparison with the typical EC studies. Here, each pair was only encoded once, and the emotional component of the pair was an imagined sentence, rather than a physical stimulus. The possibility of EC with imagined stimuli had been raised before (Baeyens et al., 1993; De Houwer, 2006; Gast & De Houwer, 2013). The results of experiment 4.2 support that suggestion and complement neuroimaging studies showing that emotional events activate similar brain regions independently of whether they are physically experienced or only imagined (S.-E. Kim et al., 2007; Sharot et al., 2007). Therefore, the findings of experiment 4.2 indicate that imagined events elicit similar emotions as physically experienced events, and those emotions can be transferred to a neutral stimulus via EC even after a single trial.

The comparison between the two experimental conditions in the encoding phase showed that the number of positive sentences created in the free condition was positively correlated with participants' scores on the self-esteem questionnaire. This is in line with experiment 4.1 showing that emotion attribution is influenced by personality traits. Moreover, EC effects were larger when participants were free to choose when to attribute positive emotions. Three explanations for this finding were raised in detail in chapter 5. In short, it is possible that the words used in positive sentences in the free condition were already more liked than the others, or that the presence of cues in the told condition decreased attention during encoding, or that the emotions attributed to positive sentences in the free condition were more intense than the ones in the told condition. Because the words were carefully matched in their valence ratings (Warriner et al., 2013) and because participants were able to use most of the words in sentences, the first two possibilities seem unlikely. Rather, the third possibility is favoured based on previous literature showing that non-verbal positive displays are more emotionally intense when they are voluntary than when they are posed (Krumhuber & Manstead, 2009; Lavan et al., 2016; McGettigan et al., 2015). So, the positive sentences in the free condition were possibly more positive than the ones in the told condition, leading to a larger EC effect.

Surprisingly, emotion attribution did not influence memory performance. That is, participants were equally accurate in remembering positive and neutral sentences. This may have happened because of the different frequencies of neutral and positive sentences in the two experimental conditions or because of the absence of negative sentences. It is also possible that the lack of memory differences was necessary for the presence of EC effects, as suggested by the Implicit Misattribution model (Jones et al., 2009)

To sum up, experiments 4.1 and 4.2 showed that, similar to what is known about emotion regulation, emotion attribution is also influenced by personality traits, and that should be taken into account in future EC studies. The two experiments also showed that participants are able to change the emotional valence of neutral information by mentally adding a negative or positive context to it. Additionally, when participants are instructed to attribute emotions but are free to decide when to do so, the attributed emotions are more intense and lead to stronger EC effects. In conclusion, experiments 4.1 and 4.2 show that EC effects are robust in controlled conditions, and maybe larger in more naturalistic settings.

Emotion attribution and memory in the ageing brain (Chapter 5)

In three experiments, the interaction between emotion attribution and memory was analysed in younger and older adults with behavioural and ERP measures. The main questions were whether EC differs between younger and older adults and how it relates to episodic memory. Moreover, experiment 5.2 manipulated memory performance to evaluate its impacts on EC, and experiment 5.3 investigated the brain correlates of EC.

Experiments 5.1 and 5.2 corroborated the findings from experiment 4.2 by showing the efficacy of the EC protocol used in this thesis. A remarkable finding emerging from these two experiments is that no age-related differences were found in EC effects. This suggests that older adults are as able to attribute positive emotion to neutral information as younger adults are. In other words, emotion attribution seems to be preserved in ageing.

Another finding from experiments 5.1 and 5.2 was the better source memory performance for positive sentences when compared to neutral sentences. That finding is, on its own, not surprising (e.g. Maratos & Rugg, 2001; Smith, Dolan, et al., 2004). The novelty of the finding lies in the imagined status of the emotional context, seeing that the effect had only been shown for physically perceived stimuli. However, this is the opposite of what was found for experiment 4.2 and this discrepancy will be discussed in the next section. More important now is that younger adults' and older adults' memory was similarly enhanced by positive emotion attribution. The idea that the relationship between EC and episodic memory is preserved in ageing is exciting because it can lead to clinical treatments in this age group, as is already done for younger adults (Engelhard et al., 2011). This idea can also be used to teach older adults that the attribution of positive emotions may work as a mnemonic technique, similar to what Dulas et al. (2011) proposed by showing a preserved self-referencing effect in ageing.

To further investigate the nature of the relationship between memory and EC, experiment 5.2 manipulated memory performance in two different ways. The experiment was designed to enhance younger and older adults' memory performance by repeating pairs of stimuli during encoding (Cohen et al., 1987), and was also designed to lower memory performance by increasing the study-test delay (Kalpouzos et al., 2008). The question of interest was whether EC effects would follow the same pattern. The methodology employed in experiment 5.2 was very similar to the one used in experiment 5.1, but during the encoding phase 1, half the items was presented only once and the other half three times each. Additionally, the retrieval and likeability phases were conducted in the same session as encoding and again seven days later in a second session.

The two manipulations were successful in altering memory performance as predicted, that is, repetition increased memory and a longer delay decreased memory. However, only the delay manipulation influenced EC effects. Results showed that EC effects were present for unique items and for repeated items but the strength of the effect did not differ between the two conditions. On the other hand, although EC effects were present in the first and in the second sessions, the strength of the effect significantly decreased with a longer study-test delay. The equal strength of EC effects for unique and for repeated items suggests that once emotion has been attributed, its effects on liking are independent of extra encounters with the stimulus (Hu et al., 2017a). The reduction in EC effects that followed the reduction in memory performance after a seven-day delay suggests that EC may be dependent on explicit memory. That is, a neutral stimulus changes its valence only if its pairing with the emotional stimulus is explicitly retrieved. This suggestion supports the Propositional Account of EC (Mitchell et al., 2009) or the Associative-Propositional model (Gawronski & Bodenhausen, 2011). To arbitrate between the two, an implicit memory task should be included in a future study that also manipulates study-test delay such as what was done here.

As mentioned before, Pleyers et al. (2007) suggested that the relationship between memory and EC should be analysed using an item-based approach. Because study 5.2

was precisely interested in how memory manipulations would influence EC, this secondary analysis was also done. It clearly showed that EC effects were only present for items that elicited correct source judgments. In fact, the items that elicited an incorrect source judgment showed a reverse EC effect. Once again, this result supports the idea that EC is only present when memory is preserved. Some authors have argued that the item-based analysis is biased because participants may use their feelings towards the stimuli to decide on the memory judgment (Hutter et al., 2012). However, experiment 5.2 had methodological strengths that the usual EC studies do not, such as the option of a “don’t know” judgment in the memory task. Thus, the amount of guessing is reduced in the current study and it is more likely that correct source judgments really were based on retrieval and not on attitudes. However, future studies could use a confidence judgment instead. That way EC effects could be compared not only between remembered and forgotten items, but also between those items that are remembered with high confidence and those with low confidence.

Experiment 5.3 looked at the neural correlates of the interaction between memory and EC. ERP prestimulus and post-stimulus Dm effects and old/new effects were also calculated and compared between valences and age groups. The mid-frontal and left-parietal effects were present regardless of valence, but a negative-going activity maximal at parietal sites was found to be larger in response to neutral words previously used in positive sentences. This activity resembles the late posterior negativity (LPN) old/new effect, linked to the mental reconstruction of the previous episode (Johansson & Mecklinger, 2003). This proposed role of the LPN fits the results of experiment 5.1 and the relationship with imagery suggested in the behavioural data. It is possible that the attribution of positive emotion during encoding increased the mental visualisation of the sentences. This enhanced imagery would then have helped later retrieval by allowing a more accurate mental reconstruction of the positive sentences, and increasing source memory performance, when compared to neutral sentences. Going even further, the LPN may be an underlying mechanism of the relationship between EC and memory. Regarding ageing, previous literature has found LPN in older adults (J. Li et al., 2004; Newsome et al., 2012; Wegesin et al., 2002) and, in the current study, no age-related differences were found in the ERP data. These results, once again, suggest that emotion attribution is preserved in ageing and may even help older adults’ memory processing.

In terms of encoding, no significant prestimulus Dm effect was found, suggesting that participants did not need to prepare for the creation of sentences. This may have happened because the stimulus duration on the screen was long (cf. experiment 3.2). Alternatively, it is possible that prestimulus activity is only seen prior to decision-making, as is the case of the vast majority of prestimulus studies in the literature (detailed and exemplified in Chapter 5). Post-stimulus Dm effects were negative-going over the left-hemisphere, but only for neutral trials. Speculatively, this may have happened because neutral sentences activated implicit associations with neutral words that were not as present when the sentence was of different valence (Schott et al., 2002). It is also possible that neutral sentences engaged a shallower encoding than positive sentences (Otten & Rugg, 2001).

To sum up, experiments 5.1, 5.2 and 5.3 investigated emotion attribution by younger and older adults and its relationship with memory. Importantly, the experiments clearly showed that presenting a neutral item only once and pairing it with an imagined emotional stimulus successfully elicited EC effects. In fact, experiment 5.2 showed that the increase in the number of presentations does not enhance the strength of EC effects. However, that experiment also showed that a longer study-test delay decreases both memory and EC, suggesting that EC effects are dependent on memory and not resistant to extinction. Stronger arguments for that suggestion came from the results of the item-based analyses, which revealed EC effects only for items that elicited a correct source judgment. A possible underlying brain mechanism of this relationship between memory and EC was unveiled by experiment 5.3. The results showed the presence of an LPN old/new effect during retrieval larger positive trials. This finding suggests that positive emotion attribution enhances the imagery of the neutral information, making it easier to be mentally reconstructed and retrieved in a later memory task. Importantly, no age-related differences were found in the interaction between memory and EC, suggesting that emotion attribution is preserved in older adults. These results are important for future research, as well as clinical and business applications.

Implications and proposed directions

Cognitive ageing

This thesis used behavioural and ERP measurements to investigate the effects of ageing on memory processing for emotional information at different time points during encoding and retrieval. Behaviourally, no overall age-related differences in memory performance were found for experiments 3.1 and 5.1. Those experiments had very different methodologies, such as different stimuli (images versus words), retrieval tasks (remember/know versus source), and the source of emotionality (stimuli versus participants). The absence of memory deficits in older adults in these two experiments goes against what is currently known about the effects of ageing on episodic memory

(Hedden & Gabrieli, 2004). However, the literature also informs of the large variability in older adults' performance (de Frias, Lövdén, Lindenberger, & Nilsson, 2007). Since the older adults tested in this thesis were mostly recruited from two institutions that provide continued learning, it is possible that those participants were in the upper extreme of the variability. Previous studies, when comparing low and high performing older adults have suggested that age-related differences disappear in the latter group (Duarte et al., 2006). So, the conclusions of this thesis should be considered in terms of healthy and successful ageing. Future studies should recruit a more diverse sample of older adults to look into the variability within this age group.

It is worth highlighting that experiment 5.2 showed a different pattern. In the first session, an overall main effect of age was found on memory performance. This effect disappeared in the second session, when both age groups showed a much lower performance. A main methodological difference between experiment 5.2 and the previous experiments can help explain the lower memory for older adults. The difference is that the sentences were spoken out loud, whereas the other two experiments did not require any verbal output. Speech production is usually slower than thought production (Iakobsen, 2003), so in order to respond to each trial in time, older adults may have had to spend less time processing the stimuli in experiment 5.2. Shorter encoding time usually leads to lower performance, as shown in experiment 3.2 and other studies (Craik & Lockhart, 1972; Memon et al., 2003; Shapiro & Penrod, 1986). For younger adults, this shorter encoding time may still have been enough, but for older adults, it may have decreased later memory performance.

In terms of the interaction between memory and emotion, experiment 3.1 showed better memory for younger adults with negative images, and better memory for older adults with neutral images. Experiments 5.1 and 5.2 did not show an interaction between memory and age. It may be tempting to conclude that emotion attribution eliminates the interactions between memory and valence in older adults, because it is a process preserved in ageing. However the results are difficult to compare due to the absence of negative valence in the experiments of Chapter 5 and by the use of images in experiment 3.1 and of the different retrieval tasks used. As discussed in Chapter 3, neutral images are usually less visually complex than positive and negative images (Erk et al., 2003), which may have aided older adults' memory. This did not occur in Chapter 5 because the stimuli were words. Thus, although it is possible that older adults process external and internal emotions in different ways and this changes the interactions between memory and emotion, this thesis cannot provide a firm conclusion on the topic.

Turning to the ERP results, it seems as though ageing does not affect encoding-related activity, either before or after stimulus onset. In both experiments 3.1 and 5.3, no age-related differences were found during encoding. Only a small number of studies in the literature have looked at encoding-related EEG in older adults. Thus, the results of this thesis expand the scarce literature and enhance the understanding of ageing effects on memory processing. As detailed in Chapter 1, Friedman et al. (1996) found that older adults had significantly smaller Dm effects than younger adults in an incidental encoding task. However, since then, Gutchess, Ieuji, et al. (2007), Friedman and Trott (2000) and Téllez-Alanís and Cansino (2004) found no age-related differences in encoding-related activity. The only study to support Friedman et al. (1996) so far has been Kamp and Zimmer (2015), but these authors do not conduct a statistical comparison between younger and older adults, so their results need to be evaluated carefully. Therefore, it seems that, although mixed, the literature suggests that ageing does not modulate ERP Dm effects. This thesis agrees with that suggestion and expands it, by also finding no age-related differences in prestimulus encoding activity.

As this thesis is being written, no published study is available regarding prestimulus encoding-related activity in older adults. The results of experiments 3.1 and 5.3 suggest that preparatory brain activity is preserved in older adults, since no statistically significant age-related differences were found. This finding is contrary to what was predicted, seeing how older adults have been shown to be less able to use anticipatory cues in task switching (Kray et al., 2005), inhibition (Hammerer et al., 2010) and expectation (Zanto et al., 2011) studies. However, those three previous studies also found worse performance in older adults. In experiments 3.1 and 5.3, no main effect of age was seen in the behavioural data. Thus, similar to what was discussed above, it is possible that the sample of older adults tested in this thesis was composed of high-performing people and does not represent the large inter-individual variability in the ageing population. Therefore, it is possible that prestimulus activity is preserved in healthy and successful ageing, aiding these older adults in memory tasks. A direct comparison between low and high-performing older participants will shed more light to this idea.

Although encoding did not show significant age-related differences, old/new effects differed between the age groups in experiment 3.1, but not in experiment 5.3. As already mentioned, the differences in results between these two experiments may have happened because of the different sources of valence (images versus participants). However, this is not clear-cut because the stimulus modality and retrieval task used were also different between the two studies. Previous research has shown that the left-parietal effect can be influenced by whether the encoded information was a word or an image (Schloerscheidt & Rugg, 1997, 2004), so any difference between in the results of experiments 3.1 and 5.3 may be due to different stimuli used. Although a direct comparison between the two experiments is not possible, the complete absence of significant age-related differences when participants engage in positive emotion attribution is interesting on its own because it can lead to clinical and practical applications.

A couple of future directions can be proposed for the study of cognitive ageing. As already mentioned, the overall performance of the older adults in this thesis was high, which does not match what the episodic memory literature predicts. Due to the large inter-individual variability in cognitive performance in older adults, it is possible that this thesis tested mostly high-performing participants. Thus, an obvious direction is to recruit participants from different sources and have a group large enough to be later divided into low and high-performing individuals. This is necessary to test the proposal that prestimulus activity is preserved in older adults, helping their memory performance. A comparison between low and high-performing older adults may also enhance the understanding of the relationship between memory and EC.

Another future direction concerning cognitive ageing is the use of memory strategies. Naveh-Benjamin et al. (2007) showed that teaching older adults encoding strategies improves their memory, but teaching them retrieval strategies has an even larger enhancement effect. This thesis supports those findings by showing that ageing effects are seen during retrieval and not encoding. Thus, if one is interested in enhancing older adults' memory performance, the focus should be on retrieval strategies.

One other future direction comes from combining findings from experiments 5.3 and 4.2. Experiment 5.3 led to the suggestion that preparatory brain activity may only be present before a decision is made. It would be interesting to calculate prestimulus Dm effects when comparing the told and free conditions in experiment 4.2. That is because it is unclear from the behavioural data, if participants only decided which emotion to attribute to the free words after seeing them or if a decision had been made beforehand. Participants could be given two conditions, one in which they should decide which valence to create before word onset and the other where they should decide only after seeing each word. That way, prestimulus activity could be analysed based on when a decision is made.

Null-findings regarding age-related differences

Some of the implications discussed above derive from the absence of age-related differences in the data. However, the lack of statistical differences between younger and older adults does not necessarily mean that the two groups do not differ. Although not common, some studies in the literature have conducted statistical analyses on each age group's ERPs regardless of the presence of an age-related effect in the global analysis (Angel et al., 2010; Berlingeri et al., 2013; Cansino et al., 2012; Cansino et al., 2010; James et al., 2016; J. Li et al., 2004). That is, in those studies, the authors calculate ERP effects for each group individually and base their conclusions on age-related differences or similarities on those statistics. This is done even when a direct statistical comparison between the groups is not conducted or when it gives non-significant results. When this type of analysis was done in experiment 3.1, prestimulus Dm effects were only present in younger adults, rather than in both groups. Also, the analysis showed that the mid-frontal old/new effect was present in older adults, rather than absent in both groups. In experiment 5.3, the individual analysis also revealed the mid-frontal effect to be present only for older adults, whereas the left-parietal effect was only present for younger adults. However, the individual analysis also confirmed that both younger and older adults show larger LPN effects for positive than for neutral trials.

Thus, the two main findings of experiment 3.1 could be challenged by the individual analysis within each age group. The first finding was that prestimulus activity is preserved in ageing and helps high-performing older adults in answering memory tasks. This suggestion is no longer valid if one considers the within-group analysis. The second finding was that the absence of left-parietal effect in older adults was not related to lower performance in this group. The individual analyses revealed that older adults had a larger mid-frontal effect, which would easily explain that ageing participants used familiarity to respond to the task, as seen before (e.g. Bastin & Van der Linden, 2003; Daselaar et al., 2006). Similarly, experiment 5.3 also found the presence of mid-frontal effect for older adults only, whereas younger adults showed left-frontal effect. Nevertheless, the main finding of experiment 5.3, which suggested that emotion attribution enhances memory performance via imagery in younger and older adults, is confirmed after the individual analysis. Thus, the idea that emotion attribution and the relationship between memory and EC does not vary with ageing is strengthened.

In conclusion, some of the ERP patterns found in this thesis considerably change depending on which type of analysis is chosen. The vast majority of ageing studies adopt the between-group analyses, corroborating the original description of those three ERP results in this thesis. However, the fact that important findings are subject to changes due to the type of analysis used strongly indicates the need of replication of the studies presented here. This is especially important considering that this thesis is the first to look at prestimulus Dm effects and EC effects in older adults, and the first to suggest an underlying neural mechanism for the relationship between memory and emotion attribution.

Emotion attribution and memory

This thesis developed a novel EC approach to study the relationship between emotion attribution and memory. Virtually the same procedure was used for experiments 4.2, 5.1, 5.2, and 5.3. The results of the four experiments showed that this novel procedure is successful in eliciting significant EC effects. In other words, imagining an emotional context for a neutral piece of information once can change the valence of that information. As already discussed throughout this thesis, this novel procedure has a main difference when compared to the methodology commonly used in the EC literature. The difference is that each pair of conditioned and unconditioned stimuli is presented only once. Presenting the pair only once has at least three advantages. First, if the same number of pairs are used, presenting them only once will logically reduce the total testing session time compared to when they are presented several times. A shorter session is particularly attractive when testing patients or older adults, who can get tired after a long session. On the other hand, if the total time of the session is kept, the single presentation of stimulus pairs allows for more stimuli to be used. That is interesting if the study also looks at contingency awareness, because it will be less likely for memory performance to reach ceiling.

A second advantage of single pair presentation in the procedure developed here relates to mere exposure effects. It is known that one's attitudes and preferences towards a stimulus can increase due to mere exposure (Bornstein, 1989; Kunst-Wilson & Zajonc, 1980). That is, people will like something more just because they have seen it repeatedly. In fact, experiment 5.2 of this thesis found that words presented three times were more liked than words presented only once, regardless of the valence of the sentence. Thus, it is possible that EC effects will be confounded by mere exposure effects when stimuli are presented in many trials. This possibility is eradicated by using the procedure developed here. Additionally, Bornstein (1989)'s meta-analysis suggests that the mere exposure effects increase up to 10 presentations, but may either reach a plateau or decrease with more presentations. Previous EC studies have used a large variety of numbers of presentation, making it difficult to compare the results between the papers. Moreover, experiment 5.2 showed that EC effects were significant after one presentation and did not increase with three presentations, so future use of the procedure developed here shall not undermine possible EC effects. This suggestion is supported by previous literature that also did not see significant differences in EC effects when comparing different number of presentations (Hofmann et al., 2010; Hu et al., 2017a).

Apart from showing the efficiency of the EC procedure developed here, this thesis also makes contributions to the understanding of how neutral information that has acquired emotionality is remembered. The main ERP finding was the presence of a negative-going old/new effect on posterior sites larger for positive trials. As detailed before, this type of activity resembles the LPN effects, which have been linked to imagery and mental reconstruction of a previous episode (Johansson & Mecklinger, 2003). Thus, this thesis raises the possibility that positive emotion attribution enhanced visualisation of the sentences, providing more source information to be retrieved later on. Importantly, this was the case for younger and older adults.

However, the relationship between emotion attribution and memory performance is not straight-forward. Experiment 4.2 found no mnemonic advantage for positive trials over neutral trials. It is not clear why this happened. The only major methodological difference between this experiment and the others was the presence of the free condition, which presented an exclamation mark instead of the facial cues. It is possible that the memory effect is somehow linked to the facial cues, but it is not possible to say for sure. In experiment 5.2, the results showed that positive trials elicited better performance compared to neutral trials, but only in the first session and only for repeated items.

One way to tackle these discrepancies in behavioural findings may be to use the statistical approach suggested by Pleyers et al. (2007) and divide the data into remembered and forgotten items. When this was done in this thesis, the results point out that it is not the case that memory is enhanced for positive trials. But rather, that memory is enhanced for trials that people think were positive, even if this thought is inaccurate. So, perhaps the correct interpretation is that positive emotion attribution increases memory only when it works. If the item does not acquire positive valence, memory for that trial will not increase. However, it is also possible that the relationship goes the other way around. That is, successful positive emotion attribution (measured by EC effects) only occurs when people explicitly remember the correct source of the item. Thus, this thesis suggests a link between memory and EC, but the nature of this relationship needs to be further explored.

One logical way to keep exploring emotion attribution and memory is to study negative emotions. In this thesis, the focus was on positive emotions because of the literature on the positivity effect (Carstensen & Mikels, 2005) and emotion regulation (Shiota & Levenson, 2009; Urry & Gross, 2010), already vastly discussed throughout the chapters. Literature suggests that negative events elicit faster responses and better memory because of their high evolutionary importance (Baumeister et al., 2001; Öhman, Lundqvist, & Esteves, 2001; Rozin & Royzman, 2001), at least in younger adults. Additionally, experiment 4.1 suggested that participants naturally add negative emotions to neutral information. So, it is possible that the relationship between negative emotion attribution and memory is different than what was found in this thesis for positive emotions. Moreover, there is a large literature on EC effects following manipulations involving fear (e.g. Hur et al., 2016; LaBar, Cook, Torpey, & Welsh-Bohmer, 2004) and electric shock (e.g. Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002) that can be used as reference for studies with negative valence. This literature uses highly arousing negative emotions. A procedure like the one used here would allow the investigation of conditioning effects without the confounding factor of arousal (cf. Bennion et al., 2013).

To better understand the relationship between memory and EC, another future direction would be to include implicit EC tasks to the procedure used here. That may help to comprehend whether memory is necessary for EC (see review by Gawronski & Walther, 2012). The few studies in the literature that have used an implicit measure found mixed results. Hu et al. (2017b) found effects of memory only on explicit EC but not on implicit EC. However, other authors found no differences between the two types of EC measures (De Houwer, 2006; Gast & De Houwer, 2013). Thus, it would be interesting to join the advantages of the procedure developed here with implicit EC tasks.

Another future direction for research is to conduct qualitative analyses of the sentences that were created during the encoding phases of experiments 4.2 and 5.2. As already mentioned, for the repeated items in experiment 5.2, participants reported remembering the sentence previously created with a word but actively trying to create a new one. Thus, the emotional unconditioned stimuli were simultaneously single and multiple. Hofmann et al. (2010)'s meta-analysis suggests that EC effects do not depend on whether or not the unconditioned stimulus varies in its identity. However, Stahl and Unkelbach (2009) found attenuated EC effects when multiple emotional stimuli are paired with the same neutral item, possibly due to how that manipulation affected source memory. Gawronski and Walther (2012) say that the comparisons between single and multiple unconditioned stimuli remain ambiguous with respect to the causal effects of memory on EC. Thus, a more in depth analysis of the sentences created may help understanding of this topic. One possibility is to have two groups of participants and to instruct one to always create the same sentence and the other to create different ones.

A future study should also address the ERP findings of experiment 5.3 and the suggestion that positive emotion attribution is related to imagery. As mentioned, this experiment found the presence of posteriorly-distributed negative-going old/new effects larger for positive trials, which were the ones that elicited better source memory. These results are not entirely comparable with those from Gonsalves and Paller (2000) and Rosburg et al., (2011a, 2011b) because those authors compared imagined conditions with perceived conditions. Thus, in order to further investigate if imagery is indeed involved in EC, future studies should add a new condition to the procedure of experiment 5.3, where sentences are written on the screen. The old/new effects for that condition would be compared with the imagined condition to test whether the LPN effects are present for positive over neutral trials and imagined over perceived trials.

Final conclusion

This thesis addressed the interactions between memory, emotion and ageing, and how neutral information acquires emotionality and is later remembered. The findings suggest that ageing impacts retrieval but not encoding-brain activity, with prestimulus activity being preserved in older adults. This thesis also developed a novel evaluative conditioning procedure, in which the two age groups are able to attribute positive emotions to neutral information, sometimes enhancing memory by facilitating mental visualization.

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