University of Reading

The Relationship between Emotion and Memory: Exploring the effects of valence across the adult life-span

Thesis submitted for the Doctor of Philosophy

School of Psychology and Clinical Language Sciences

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Declaration: I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Jasmine Raw

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The research presented in Chapter 3 is published.

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Abstract

Emotional items are often remembered better than neutral items regardless of valence however, positive and negative emotions sometimes lead to differential effects on memory. This variance is particularly prominent between laboratory-based memories and real-life autobiographical memories. Additionally, valence-related patterns on memory are known to change with age; older adults frequently demonstrate a preference for positive over negative information. According to the Socio-Emotional Selectivity Theory (SST), this *positivity effect* is the consequence of emotion-related goals becoming more important as future time perspective decreases with age. Although the theory provides an explanation for age-related differences in emotional processing, not all of the SST's predictions have been supported.

This thesis therefore explores the relationship between emotion and memory across the adult life-span. Specifically, Study 1 examines autobiographical memories for an emotional event to understand whether valence leads to differences in memory and if they differ as a function of chronological age. Study 2 explores this relationship further in a controlled laboratory setting and obtains neural and behavioural measures to test the predictions of the SST. Meanwhile, Study 3 expands on Study 2 to evaluate the predictions of the SST across three separate measures of emotional processing: memory, neural activation and emotional well-being.

Overall, the results from Study 1 showed differential effects of valence on memory for autobiographical memories, but failed to find age-related effects to support the SST.

However, in Study 2, older adults exhibited the positivity effect in memory which may be explained by the significant age-related differences in neural activity during emotional processing. Finally, age-related differences were found in emotional well-being (Study 3), however, not all predictions of the SST were supported, particularly the concept of future time perspective. In summary, mixed support for the SST was found suggesting the theory may not fully account for all age-related differences in emotional processing.

Contents

General Introduction

In this first chapter, the effects of emotion on memory are reviewed in order to highlight the current limitations in our understanding. The enhancing effects of emotion are often attributed to the effects of arousal, yet there is evidence to suggest that valence can differentially modulate our memories too. This chapter firstly briefly considers the effects of emotional arousal on early emotional processing, including attention and perception, before concentrating more heavily on the effects of emotional arousal on memory. At this point, the chapter reviews evidence which shows that emotional arousal can have both enhancing and impairing effects on memory and then further discusses the critical role of the amygdala in the formation of emotional memories.

In the second chapter of the introduction, the effects of valence and age on memory are discussed. Here, important theories on why the effects of valence on memory change with age are critically reviewed. The remaining chapters in this thesis comprise of three separate chapters, each dedicated to a single study. The first two studies, covered in Chapters 3 and 4 were conducted to understand the role of positive and negative emotional valence on long-term memory and whether this differs with age. The first longitudinal study particularly concentrates on memory for a real-life event and examines how valence affects long-term autobiographical memory consistency, vividness and confidence. It further explores the effects of age and the role of possible mediators such as rehearsal and importance. The second study, conducted in a controlled laboratory setting, used both functional magnetic resonance imaging (fMRI) and behavioural measures to examine episodic memories for emotional stimuli among younger and older adults. Here, we looked more specifically at the age-related differences frequently observed in memory for positive versus negative stimuli by examining the differences in neural responses to positive, negative and neutral images between younger and older adults. The third study, covered in Chapter 5, extends on the work of study 2 (Chapter 4) by utilizing the neural and behavioural data from the same participants to test the predictions of a key theory that proposes a reason for these age-related differences. Importantly, this chapter also additionally explores affective experiences in daily life through the use of experience sampling to understand the complex relationship between affective responses observed in the laboratory and emotional well-being in daily life. Collectively, across the three empirical chapters, we have utilized different methodologies and examined both autobiographical and episodic memories formed within and outside of the laboratory, to understand the combined effects of valence and aging on memory, neural responses and experienced emotions in daily life.

Definition of emotion

It is well known that emotion can influence the way we think and behave but the concept of emotion is rather ambiguous. Indeed, there is not one concrete definition that is used consistently throughout the literature. In fact, in 1981, researchers identified 92 separate definitions from text books and journals (Kleinginna & Kleinginna, 1981) demonstrating not only its wide-reaching scope for scientific exploration but equally the diversity in its interpretation. Therefore, while attempts have been made to define emotion, the complex nature of emotion seem to prevent it from being constrained to one single definition. More recently, Izard (2010) suggested that researchers studying emotion should explain and contextualize what they mean by “emotion” in order for research in this area to progress more smoothly. Therefore, in the current thesis, the term “emotion” will be understood using the Circumplex Model of Affect (Russell, 1980) in which emotion is considered as a linear combination of two factors: valence and arousal.

Defining Valence and Arousal

Referring to emotion as a construct that is comprised of two dimensions (valence and arousal) derives from Russel's (1980) Circumplex Model of Affect. Valence is often thought of as how positive or negative something is while arousal is the degree of calmness or excitation that a stimulus evokes. Although they are considered as two separate dimensions, when combined, the combination of high or low arousal and negative or positive valence can be translated into a certain emotion (see Figure 1.1.).

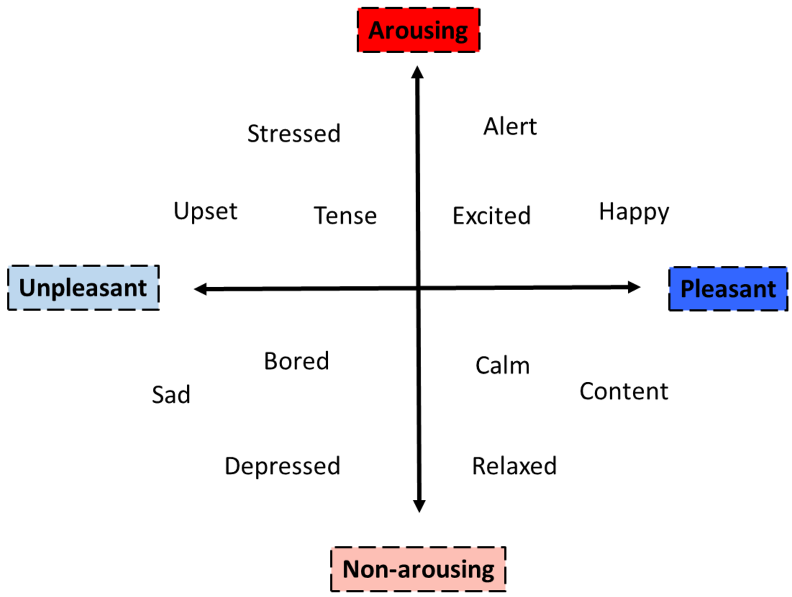

Figure 1.1. Adaptation of the Circumplex Model of Affect

Arousal is often accompanied by heightened physiological activity (Mather & Sutherland, 2009) thought to be a consequence of an individual's sympathetic autonomic nervous system being activated. Early work, in which participants were shown images that varied in valence and arousal, found that skin conductance responses co-varied with arousal ratings, suggesting that arousal had an effect on our sympathetic nervous system (Lang, Greenwald, Bradley, & Hamm, 1993). Subsequent research also found that pupil sizes increased more when participants viewed emotionally arousing images and again, these changes co-varied with skin conductance responses (Bradley, Miccoli, Escrig, & Lang, 2008).

An aroused human or animal will experience an increase in their visceral state through sweating more and having a faster heart rate (Lang, Greenwald, Bradley, & Hamm, 1993) . For example, when individuals are presented with highly arousing images, their pupil size (Bradley et al., 2008; Hämmerer et al., 2017), heart rate (Brosschot & Thayer, 2003; Gomez & Danuser, 2010) and skin conductance measures increase (Anderson, Yamaguchi, Grabski, & Lacka, 2006; Bradley & Lang, 2015; Bradley et al., 2008; Gomez, von Gunten, & Danuser, 2016). These physiological reactions are thought to reflect the early stages of an individual's response to either appetitive (e.g. an image of appetizing food) or aversive (e.g. a gruesome image containing blood) stimuli during which an individual is gearing up to take the necessary action of approach or defence.

Valence on the other hand, ranges from unpleasantness to pleasantness, with neutral being centrally placed in between the two. Like arousal, valence has been associated with physiological responses too. For example, it has been demonstrated that the specific content of pleasant (e.g., erotic vs. adventure) or aversive picture stimuli (e.g., threat vs. victim) can differentially modulate physiological responding (Bradley, Codispoti, Cuthbert, & Lang, 2001; Yartz & Hawk Jr, 2002) and whereas the effects of arousal can dissipate quite quickly, the effects of valence are thought to be more long-lasting (Gomez, Zimmermann, Guttormsen Schär, & Danuser, 2009). In addition, when pictures are positively valenced such as those depicting a romantic theme, then an individuals' startle probe response is weaker in comparison to responses for negatively valenced images (Bradley, Codispoti, Cuthbert, et al., 2001; Vrana, Spence, & Lang, 1988).

Beyond the physical effects valence and arousal reportedly have on our physiological systems, emotion is also thought to interact with cognition (Ochsner & Gross, 2005; Richards & Gross, 2000). Although once studied as two completely separate entities, contemporary researchers, generally speaking, acknowledge the important relationship between emotion and cognition (Lindquist & Barrett, 2012; Pessoa, 2008). Importantly, there is now a substantial amount of empirical work that demonstrates the influence of emotion on cognitive processes such as attention and episodic memory (Dolan, 2002; Dolcos, Iordan, & Dolcos, 2011; Öhman, Flykt, & Esteves, 2001; Pessoa, 2009; Phelps, 2004). Importantly, this theory holds when emotion is interpreted in terms of valence and arousal. In fact, specific effects of valence and arousal on memory have been documented. For example, valence has been shown to affect memory through the recruitment of different processes during encoding (Mickley & Kensinger, 2008) while emotional arousal is known to enhance memory for emotional stimuli (Dolcos, Labar, & Cabeza, 2004; Kensinger & Corkin, 2004). Moreover, events that elicit emotional arousal are often remembered better than for neutral, non-arousing events (e.g. Buchanan & Adolphs, 2002). Therefore, the aforementioned evidence would suggest that valence and arousal are important factors to consider when understanding the effects of emotion on cognition, particularly memory.

In this thesis, the effects of emotional arousal, including the stress hormones associated with increased arousal, on memory are firstly reviewed however, the subsequent chapters focus more specifically on the effects of positive and negative valence on memory and how the relationship between valence and memory changes with age.

1. Chapter 1: The Effects of Emotion on Cognition

Often the most memorable moments in our lives are ones that were accompanied by an intense emotional reaction; the day we got married or welcomed the birth of a child or the day we lost a loved one. Unlike our memories for everyday events that we often quickly forget, our memories for emotional events are often much more long-lasting. Even months and years later, we claim to recall these events with a great sense of vividness and proclaim to remember them in great detail, as if it happened only a short time ago. It is this durability and increased sense of vividness and confidence that often distinguishes these memories from others and what has inspired researchers to investigate them. Yet this emotion-enhancing benefit is not a new concept. In fact, it has long been known that emotional experiences can improve our memory (James, 1890) yet still, over a century later, it is a topic at the forefront of empirical research but with many questions still remaining unanswered.

There is a plethora of research which demonstrates this emotion-enhancing benefit on memory in which events that have emotional significance are remembered better than those that do not (M. A. Conway, 1990; Dolcos & Cabeza, 2002; Madan, Caplan, Lau, & Fujiwara, 2012; McGaugh, 2013; Rubin & Kozin, 1984; Schaefer & Philippot, 2005). This effect has been replicated in laboratory-based settings for words (Kensinger & Corkin, 2003; Kleinsmith, Kaplan, & Trate, 1963; LaBar & Phelps, 1998; Sharot & Phelps, 2004), pictures (Bradley, Greenwald, Petry, & Lang, 1992; Ochsner, 2000), film clips (Cahill et al., 1996) and even sounds (Bradley & Lang, 2000). Additionally, the effect is also evident in real-life settings in the form of our autobiographical memories (Berntsen & Rubin, 2002; Brown & Kulik, 1977; D'Argembeau, Comblain, & Van der Linden, 2003; St. Jacques & Levine, 2007) for both personal and public events too (Neisser & Harsch, 1992).

Since emotional items and events are typically more salient, they often benefit from faster and more efficient early processing compared to neutral information (for a review see LaBar

& Cabeza, 2006; Mather, 2007). For example, highly arousing stimuli are more likely to capture and maintain our attention (Anderson, 2005; Calvo & Lang, 2004) which has been shown to have beneficial effects on our subsequent memory (Dolcos & Cabeza, 2002; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008). It is also thought that emotion biases the competition for processing resources (Desimone & Duncan, 1995), like attention, in which the emotional information gains priority over competing neutral information (Mather & Sutherland, 2011).

This ability to selectively attend to important information while ignoring unimportant information is beneficial and reduces the amount of information we are required to process. From an evolutionary perspective, remembering emotional events has practical implications in terms of our survival as it allows us to detect and remember threats and how to avoid them in the future. For example, humans demonstrate the ability to automatically detect survival-relevant stimuli such as guns and snakes (Öhman et al., 2001). Therefore, remembering something that evoked an affective response may allow us to make better predictions, and adapt our behaviour to future situations more appropriately (Klein, Cosmides, Tooby, & Chance, 2002; McGaugh, 2013; Nielson, Yee, & Erickson, 2005) which in turn, increases our chances of survival. While we may not rely upon this function at such a primitive level as we once used to, it is still an innate mechanism that exists in both animals and humans (Cahill & McGaugh, 1998).

1.1 The Effects of Emotion on Attention and Perception

Before a memory can be formed and later recalled, we must first attend to and then process the information. These earlier stages of attention and perception are also known to be influenced by emotion which can lead to memory enhancements (Christianson & Loftus, 1991; Hamann, Ely, Grafton, & Kilts, 1999; Reisberg & Heuer, 1992; Talmi et al., 2008). Outside the context of emotion, attention is a mechanism through which information is selected or ignored. We are continuously bombarded with visual stimuli that compete for our attentional resources. Therefore our brain has to allocate its resources appropriately so that we can choose what is important and what is not. When we try to attend to multiple things at once, our subsequent memory performance is often poorer (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Ninio & Kahneman, 1974). Therefore selectively attending to fewer things can improve our subsequent memory performance. This function or ability, known as selective attention, is thought to contribute to our ability to remember things. Since our memory has a limited capacity i.e. we cannot remember absolutely everything, our attention is thought to help us decide what should be encoded (Chun & Turk-Browne, 2007; Fernandes & Moscovitch, 2000).

Often, the things that attract our attention are visually salient; for example, an object that is brightly coloured among objects that are dull, or an object that is moving faster among objects that are moving much slower. When such objects have these distinct visual features, they are more likely to attract our attention (Itti & Koch, 2001). These are examples of bottom-up factors. However, there are top-down factors that can influence our attention too such as our prior knowledge or goals (Mather & Sutherland, 2011). For example, if we are at a busy airport waiting to pick up a family member, we can implement our prior knowledge of what the person looks like to help us detect them more quickly, while also actively dismissing people that do not fit their description. In both scenarios, the visually salient items and the items that match our top-down goals are given priority status.

1.1.1 Enhancing effects of emotional arousal on attention and perception

Even in the absence of emotion, attention is thought to modulate the competition for mental representation between stimuli. However when emotion is included in this equation, it is thought to bias this competition in favour of emotional items. The arousal biased competition (ABC) theory (Mather & Sutherland, 2011) explains that emotion (defined here as arousal) can amplify the effects of competition in attention leading to a case of a "winner-takes-more" effect for the high-priority information.

Supporting the idea that arousal biases the competition in favour of emotional items, research has shown that emotional stimuli benefit from faster, more efficient, and more extensive early processing (for a review see LaBar & Cabeza, 2006). Moreover, they are more likely to capture our attention compared to neutral information (Calvo & Lang, 2004). Threatening information in particular, preferentially attracts our attention (Anderson & Phelps, 2001) over non-threatening stimuli; a pattern that is even seen in infants (Lobue & Deloache, 2010) as well as preschool children and adults (LoBue & DeLoache, 2008). Being able to quickly attend to threatening stimuli is thought to reflect an innate survival function that can increase our chances of survival by allowing us to quickly detect known threats.

Even before people are consciously aware of a stimulus, its emotional status can generate an automatic response. This is particularly evident in studies using event-related potentials (ERPs) which measure electrical signals within the brain. In several studies, it has been found that electrical signals following emotional stimuli are larger within the first 200-300ms following stimulus onset than they are following neutral stimuli (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Schupp et al., 2004). In the laboratory, peoples' attentional preference to threatening stimuli is often tested using visual-probe tasks that use threatening images of snakes, spiders or emotional faces as well as non-threatening images of flowers or neutral faces. The images are briefly presented (e.g. around 75ms) simultaneously (one on the left of the screen and one on the right) before being replaced by a probe stimulus that is located on either the left- or right-side of the screen. In such tasks, participants are required to identify the probe stimulus as quickly as possible and their reaction times are measured. Often, the reaction times to probes that follow a threatening image are typically faster (Armony & Dolan, 2002; Eastwood, Smilek, & Merikle, 2001; Lundqvist & Öhman, 2005; Ohman, Flykt, & Esteves, 2001), even when the location of the probe stimulus appears in an unexpected location to what may have been anticipated by the participant. Findings such as these suggest that there is an attentional bias to threatening information (Holmes, Bradley, Kragh Nielsen, & Mogg, 2009) which increases our ability to detect salient stimuli in our environment.

Emotion has also been found to increase our perception. In experiments where participants are presented with a series of images that are presented in quick succession, like that of a rapid serial visual presentation (RSVP) paradigm, participants often fail to detect the second target image when it is presented shortly after the first. This phenomenon is known as the attentional blink (Raymond, Shapiro, & Arnell, 1992) and reflects a lack of awareness of the second target since attentional resources are allocated to the processing of the first one. Emotion however has been found to modulate the attentional blink (Anderson & Phelps, 2001; Maratos, Mogg, & Bradley, 2008) and can in fact increase the awareness of the second target stimulus. For example, Maratos and colleagues (2008) presented participants with schematic faces including four valenced faces that were used as target stimuli. Their results showed that performance was better on trials in which the second target was an angry face as opposed to a neutral one suggesting that the presence of a negative face increased perception. Likewise, using healthy adults and patients with amygdala damage, Anderson and Phelps (2001) found that healthy adults strongly benefitted from the inclusion of aversive stimuli in their perception of the second stimulus while no such benefit was found for patients with amygdala damage. The theory being that the amygdala is essential in detecting arousing information.

Collectively, the previous studies provide evidence showing that emotion can have enhancing effects on our attention and perception. This increase in attention is thought to have beneficial effects on our ability to encode information which is when the initial memory representation is thought to be formed (Hamann, 2001). Therefore, it would be reasonable to assume that greater attention leads to better memory. This concept is in fact supported by the attention mediation hypothesis which suggests that the effects of emotion on memory are mediated by attentional processes (Talmi et al., 2008).

1.2 The Effects of Emotion on Episodic Memory

As previously discussed, emotional arousal, often thought of as the "intensity" of a stimulus, is known to influence cognition, such as attention (Davis & Whalen, 2001; Fox, Russo, Bowles, & Dutton, 2001). Importantly, it is also known to affect memory. For example, emotionally arousing events are often remembered better than neutral ones (Buchanan & Adolphs, 2002; Dolcos & Cabeza, 2002; Madan et al., 2012; McGaugh, 2013) with greater levels of vividness and detail that withstand the test of time (LeDoux, 2000). Some believe that this is because emotionally arousing events are so unique that they grab and sustain our attention (for a review see Dolan & Vuilleumier, 2003), leaving fewer cognitive resources to process other non-emotionally arousing details.

Early research surmised that the level of arousal that was experienced could influence memory performance by limiting the number of resources we could attend to (Easterbrook, 1959). Mirroring Yerkes and Dodson's (1908) theory about the relationship between pressure and performance, the effects of arousal on memory performance were thought to follow a similar inverted U-shape pattern. That is, lower levels of arousal are not enough to evidence enhanced memory performance however, when medium levels of arousal are experienced, performance is more optimal. Experiencing too much arousal however could have a detrimental effect altogether; thought to be a consequence of attentional narrowing (Easterbrook, 1959). Evidence of this inverted U-shaped curve was provided across animal and human studies that examined the effects of stress hormones, such as glucocorticoids that are released following an emotionally arousing experience, on memory. They found that moderate levels of the stress hormones experienced during learning enhanced subsequent memory but lower or higher doses showed either an impairing effect (e.g. Lupien & McEwen, 1997) or no effect at all (e.g. Roozendaal, Williams, & McGaugh, 1999).

Besides studies examining the effects of stress hormones on memory, additional support for Easterbrook's theory comes from clinical studies involving highly anxious individuals. Such individuals are believed to experience greater levels of emotional arousal compared to low anxious individuals and even in the absence of a change in physiological arousal, rate emotional images as more arousing than healthy controls (Rosebrock, Hoxha, Norris, Cacioppo, & Gollan, 2017). In one study in which highly anxious individuals were presented with aversive images, it was found that they were less likely to remember information beyond the aversive aspect of the image (Mathews & Mackintosh, 2004). In other words, those participants with high levels of anxiety appeared to experience attentional narrowing to the central features of a negative image to a greater degree than those who were less anxious. Therefore the findings offer support to Easterbrook's hypothesis that too much arousal can have a detrimental effect by narrowing attention to the most salient aspect of an event.

However, this particular theory later received criticism, as the effects of arousal on memory performance do not always follow this pattern. For example Christianson and Hübinette (1993) interviewed both victims and bystanders who had been caught up in bank robberies, presuming that the victims would have experienced higher levels of arousal compared to those who were simply bystanders. However, it was the victims who offered more accurate accounts for the central details of the events suggesting that higher levels of arousal led to better memory. More recently, the passengers of an aeroplane that ran out of fuel while flying over the Atlantic Ocean (flight AT236) were assessed on their memory for the traumatic experience that almost ended in disaster (McKinnon et al., 2015). When comparing their memory for the flight, which was assumed to be a highly negative and highly arousing event, with their memory for the 9/11 terror attacks as well as a non-emotional event, the researchers found that memory for the details of the flight were in fact enhanced. Therefore, for these individuals, the higher levels of experienced arousal led to better long-term memory. Besides this experiment, studies involving low to moderate levels of arousal have also been found to have enhancing effects (Mather, 2007) just as studies with higher levels of arousal (Peterson & Whalen, 2001) have too. Therefore, experiencing high emotional arousal does not necessarily preclude any form of memory enhancement, just as experiencing lower levels of arousal can actually lead to better memory performance. Instead, there is a growing consensus among memory and emotion researchers that the effects of arousal on memory are in fact selective (see Mather & Sutherland, 2011 for a review) and that older theories such as Easterbrook's attentional narrowing are not comprehensive enough to explain the complexities that arousal has on memory.

1.2.1 Emotional enhancement versus emotional impairment

Several theories touching upon the paradoxical effect of the enhancing versus impairing effects of arousal on memory have been proposed over the years and are now understood more broadly as memory-trade off theories. Across these theories, it is generally understood that our memories for emotional events are not completely accurate and in fact are often fragmented. In other words, while our memory for some aspects of an emotional event can be extremely vivid and accurate, our memory for other aspects are often more hazy (for reviews, see Buchanan & Adolphs, 2002; Reisberg & Heuer, 2004).

One collection of theories, such as *memory narrowing* and the *weapon focus effect*, all fit with the idea that emotional arousal results in memory narrowing due to the constraints placed on our attentional resources during a highly stressful or emotional event, similar to what Easterbrook had once suggested. According to these theories, this results in individuals being able to remember the most salient information but at the expense of other less salient information, possibly due to attentional biases towards emotional information (Loftus, 1979a). This bias is even evident when participants are instructed towards other tasks or told to explicitly ignore the arousing stimuli suggesting that highly arousing stimuli still attract our attention and resources (see Iordan, Dolcos, & Dolcos, 2013 for a review).

One fruitful area of empirical work where this pattern was further evidenced was in eyewitness testimony research. These studies often found that witnesses of a crime were more likely to recall the details of the weapon used by the perpetrator than they were to remember the visual details of what the perpetrator looked like, such as their hair or eye colour or what clothes the perpetrator was wearing (Loftus, 1979b; Steblay, 1992). Subsequent research has replicated these findings in the laboratory (see Fawcett, Russell, Peace, & Christie, 2013; Kocab & Sporer, 2016 for reviews) using slides (Kramer, Buckhout, & Eugenio, 1990), videos (Carlson & Carlson, 2012), simulations (Pickel, Ross, & Truelove, 2006) and more recently using virtual reality (K. Kim, Park, & Lee, 2014). Whether the weapon-focus effect occurs due to the threatening nature of the weapon or whether it is in fact due to the novelty of the object (which is commonly a weapon throughout the literature) is still a matter of debate, however, the large body of evidence showing the weapon-focus pattern highlights the real-life impact that emotional arousal can have on memory. Therefore understanding the effects of emotional arousal on memory and in particular what is and what is not likely to be remembered, has important real-life implications, especially in cases of eyewitness memory.

Throughout the literature, similar patterns to the weapon-focus effect have been found in which emotional arousal is associated with impaired memory for the non-salient or peripheral aspects of an event but is equally associated with enhanced memory for the salient or central features of an event (Kensinger, Garoff-Eaton, & Schacter, 2007a). Like the weapon-focus effect, patterns like these are commonly referred to as a central versus peripheral trade-off (for reviews, see Levine & Edelstein, 2009; Reisberg & Heuer, 2004). The central details of an event typically include the emotional item such as a weapon, whereas the peripheral details often concern the neutral background information. The peripheral information can be peripheral in terms of proximity i.e. how close or far away it is from the emotional item as well as peripheral in temporal terms i.e. when it is presented in relation to the emotionally arousing item (e.g. before or after; Kensinger, 2009b).

In one such study, investigating the central versus peripheral trade-off conducted by Kensinger and colleagues (2007a), participants were presented with images of emotional (negative) and neutral objects that were superimposed onto neutral backgrounds (or scenes). In the memory test, participants were presented with objects and scenes separately and were asked to indicate if the objects and scenes were the *same* as the originally studied item, if they were *similar* or if they were in fact *new.* They found that memory for emotional objects was better than memory for neutral ones but more importantly, found that memory for neutral background scenes was worse when the object was emotionally arousing. These results suggest that memory for the central item, when it is emotionally arousing, impairs memory for the peripheral background information i.e. a central versus peripheral trade-off. Similar patterns have also been seen for emotional words and when the peripheral information is considered to be peripheral in temporal terms. For example, Strange and colleagues conducted an experiment in which participants were presented with a list of neutral words that also had emotional words embedded into it (Strange, Hurlemann, & Dolan, 2003). As expected, participants showed better performance for the emotional words but interestingly, showed poorer performance for the neutral words that were presented just before an emotional one suggesting that the emotional words resulted in retrograde amnesia or memory loss for nearby neutral information. Similarly, when participants were presented with sequences of pictures, negative oddball images included in the sequence resulted in poorer memory for preceding neutral stimuli (Hurlemann et al., 2005). In other words, when emotional stimuli are presented, it can reduce the likelihood of individuals from remembering nearby neutral information.

Although many studies using different stimuli often yield similar results, it is possible that different processes are utilized when a participant is presented with complex scenes that contain an emotionally arousing object versus when they are presented with a single emotional object or emotional word. Another limitation is that defining the central versus peripheral features of stimuli is not always as straightforward as separating features into these distinct central versus peripheral categories. As Levine and Edelstein (2009) question in their review, *what exactly is the central element of an emotional event?* Is it what people have been visually or acoustically attending to or could it be what forms the most integral part of an emotional experience? By classifying stimuli in this way, the selective effects of emotional arousal on memory do not always match with the predictions of the theory. For example, some researchers have found that both the central and peripheral details of emotional slides and accompanying narratives are remembered well (Laney, Campbell, Heuer, & Reisberg, 2004).

Nevertheless, the idea that emotional arousal can both enhance and impair memory has led researchers to explore this concept further. Another type of memory trade-off concerns the gist versus the detail in which the gist is considered to be the overall theme whereas the detail concerns the more specific features (Adolphs, Denburg, & Tranel, 2001). Whereas the gist is often assessed by getting participants to recall or recognize the emotional stimuli through verbal descriptions (e.g. “a dead person had been found in a forest”) or through probing questions such as asking who the main character was (Adolphs, Tranel, & Buchanan, 2005), the detail is often assessed by asking participants to correctly identify the correct original stimulus from one that is similar in appearance but has been altered or is different to the original in some way. In these such studies, emotional arousal has been found to enhance memory for the *gist* but impair memory for the visual details (e.g. Burke, Heuer, & Reisberg, 1992). In one such study, Denburg and colleagues (Denburg, Buchanan, Tranel, & Adolphs, 2003a) showed participants, positive, negative and neutral scenes and subsequently used three different types of memory tests; a recognition and a recall test to assess memory for the gist and a forced-choice recognition test to assess memory for the visual details. While emotional arousal enhanced gist memory, memory performance was poorer for emotional items in the forced-choice recognition compared to neutral ones. In other words, when participants were presented with the original scene and three foil scenes and were required to determine which scene was the exact one they saw before, memory performance was poorest for negative scenes.

However, there are other similar studies that fail to find support for the gist vs. detail trade-off theory. Instead, other studies have found that emotional arousal actually enhances memory for the specific visual details of an item or object (Kensinger, Garoff-Eaton, & Schacter, 2006, 2007b; Mather & Nesmith, 2008). For example, when images are negative (emotionally arousing) as opposed to neutral, participants are better at being able to determine whether the image is in fact the same as the previously studied item or if it is similar **(Kensinger, Garoff-Eaton, et al., 2006).** ***In other words, emotional arousal can facilitate memory for the specific visual details of a stimulus. It is possible that the reason for these differences is due to the differences in stimulus complexity. In Kensinger's work whereby negative emotion lead to better memory for the specific visual detail, the images presented to participants were single objects rather than more complex scenes like those that were presented in Adolph, Denburg and Tranel's experiments. Therefore, predicting the effects of emotional arousal on subsequent memory is not as straightforward as separating stimuli into central versus peripheral details or into the gist versus the detail.***

1.2.2 The Arousal Biased Competition Theory

A more recent theory, known as the Arousal Biased Competition (ABC) Theory proposed by Mather and Sutherland (2011), helps to resolve some of the inconsistencies in determining what will and will not be remembered as a consequence of experiencing emotional arousal. They explain that the likelihood of something being remembered is firstly determined by its priority, whether that be through bottom-up salience or top-down goals. For example, a stimulus can be considered a priority based on its bottom-up perceptual features such as its colour, its size or even its orientation or it could be considered a priority based on an individual's top-down goals, knowledge or expectations. Either way, if a stimulus is considered a priority, it will be considered as important and will receive the attentional resources necessary for encoding meaning that it will more likely be remembered. On the other hand, if it is not considered a priority, it will most likely be ignored meaning that it will not receive the same amount of processing resources. As such, the ABC theory helps to explain why there is sometimes a central versus peripheral trade-off, especially if the central item is emotional and the peripheral information is neutral. In other words, the theory considers that whatever is deemed the priority is more likely to be remembered.

1.3 The Underlying Mechanisms of Emotional Memory Enhancement

While there have been substantial theoretical advancements in predicting the effects of arousal on memory, it is equally important to understand the processes that lead to such selective effects. Over time, and with the development of more modern methodological techniques such as functional magnetic resonance imaging (fMRI), researchers began to concentrate their focus on understanding the underlying mechanisms that were responsible for this emotional memory enhancement versus impairment. Evidence from human and animal studies both suggest that arousal enhances memory through biological and neural mechanisms (McGaugh, 2004a). A significant finding from this line of research implicated certain brain regions that are activated under states of arousal which were then later identified as areas that are important in the formation of emotional memories too. These regions include the amygdala, which is commonly activated when people are presented with highly arousing stimuli, (Kensinger & Corkin, 2004; Mickley & Kensinger, 2008) and the hippocampus, which is known for its importance in helping individuals form memories, particularly long-term memories (Eichenbaum, Otto, & Cohen, 1992; Henke, Buck, Weber, & Wieser, 1997).

1.3.1 The Role of the Amygdala

As previously mentioned, a key region involved in the emotional enhancement of memory is the amygdala. It is an almond-shaped group of nuclei located within the medial-temporal lobe of the brain and is integral for processing emotions (LeDoux, 2000; McGaugh, 2004b; Phelps, 2006). Its role in strengthening emotional memories and in the encoding and retrieval of emotional items is well documented within the literature (Dolan, Lane, Chua, & Fletcher, 2000). Much of our early understanding on the role of the amygdala came from animal studies using rats and monkeys, particularly those experiments using classical Pavlovian fear conditioning paradigms. In such studies, a neutral stimulus, or conditional stimulus (CS), such as a tone is repeatedly paired with an aversive stimulus, or unconditional stimulus (US), such as white noise or an electric shock. After several pairings, the neutral stimulus is then found to trigger the fear response, like an increased heart rate, even when the US is no longer present (see LeDoux, 2000 for a review). When the amygdala in rhesus monkeys was removed, the monkeys began to display reduced fear responses (Klüver & Bucy, 1937) highlighting its importance for animals to acquire fear to possible threats. Similar findings have since been replicated in humans which have shown that the amygdala is activated during fear-conditioning tasks (Alvarez, Biggs, Chen, Pine, & Grillon, 2008; Knight, Smith, Cheng, Stein, & Helmstetter, 2004) and when damaged, results in reduced fear responses (Adolphs, Tranel, & Damasio, 1998). This early research therefore highlighted the amygdala's central role in detecting emotions and acquiring emotional memories.

Subsequently, the amygdala has also been found to play an important role in the very early stages of emotional processing and to be integral in facilitating the attention and perception of emotional stimuli (Phelps & LeDoux, 2005). Anatomical evidence shows that there are both direct and indirect pathways between the amygdala and visual cortex which is thought to enhance sensory processing (Pessoa & Adolphs, 2010). As such, the amygdala responds to emotional material quite rapidly, even before there is explicit awareness (Whalen et al., 1998). For example, when threatening stimuli are visually presented but not explicitly attended to by participants, the amygdala shows activity (Vuilleumier, Armony, Driver, & Dolan, 2001). Conversely, when it is damaged, individuals show impaired attention for emotional stimuli (A. K. Anderson & Phelps, 2001).

Besides its important role in the attention and perception of emotional stimuli, amygdala activity has also been found to correlate with emotional arousal (Cunningham, Raye, & Johnson, 2004; Morris et al., 1996; Wallentin et al., 2011) regardless of whether the emotional stimuli is positive or negative (Cunningham, Van Bavel, & Johnsen, 2008; Hamann, Ely, Hoffman, & Kilts, 2002; S. H. Kim & Hamann, 2007). In one study participants were presented with negative and neutral images whilst inside the MRI scanner and were asked to rate the intensity (arousal) of each one (Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). The researchers conducting the study found that the increase in intensity ratings of the images was associated with increased activation in the amygdala. Interestingly, in the same study, the higher intensity images were more likely to be recalled in a surprise memory test (Canli et al., 2000) highlighting the amygdala's additional role of strengthening memories for emotional items.

There is now an abundance of research that implicates the importance of amygdala activity in the formation of emotional memories (Adolphs, Tranel, & Denburg, 2000; Cahill & McGaugh, 1998; Hermans et al., 2014; LaBar & Phelps, 1998; Roozendaal, McEwen, & Chattarji, 2009). Moreover, research in humans with amygdala lesions has shown that the enhancement of emotional memory is weakened or is no longer evident suggesting that the amygdala is essential for emotional memories to be formed. For example amygdala-damaged patients do not show an advantage in memory for emotional material compared to neutral stimuli (Adolphs, Cahill, Schul, & Babinsky, 1997; Cahill, Babinsky, Markowitsch, & McGaugh, 1995) but still demonstrate normal memory performance for neutral information (Cahill et al., 1995). Furthermore, when the amygdala is temporarily inactivated through means of administering certain drugs such as beta-blockers, then the memory enhancing effects can be weakened (McGaugh, 2004a). For example, when healthy adults are administered propranolol, a frequently used beta-blocker drug which antagonizes the adrenergic system, prior to learning a story, they typically demonstrate similar behaviour to amygdala-damaged patients (Cahill, Prins, Weber, & McGaugh, 1994). In other words, compared to participants in the placebo group, they show emotional memory deficits. Therefore collectively, the evidence would suggest that the amygdala plays a key role in the processing of emotion and in the facilitation of emotional memories. However, it is important to note that the amygdala is not considered to be part of the brain that is responsible for storing memories, rather it is its connections to other brain regions, such as the hippocampus, which are thought to facilitate the storage of emotional memories.

As has previously been discussed however, emotional arousal has selective effects on memory meaning that it is often the most salient aspects of an event that are well remembered. Therefore, increased amygdala activity does not necessarily result in heightened memory for everything but rather increases the likelihood that the emotional information will be remembered. Neuroimaging research has shown that the activity in the amygdala during encoding and its functional connectivity with the medial temporal lobe can predict subsequent memory performance for emotional stimuli (Dolcos, LaBar, & Cabeza, 2004; Ritchey, Dolcos, & Cabeza, 2008). However, its enhancing role seems to be specific to emotional material since neutral information does not appear to benefit from amygdala activation (e.g., Cahill et al., 1994; LaBar & Phelps, 1998).

1.3.2 Memory consolidation

Since the amygdala is a very well connected region of the brain that has strong links to several cortical and subcortical regions (Amaral, 2003), it is able to exert its influence on other brain regions in order to guide attention and modulate memory. For example, neuroimaging studies show that there are strong correlations between amygdala and hippocampal activity during the encoding of emotional information (Dolcos et al., 2004; Kensinger & Corkin, 2004). Across many neuroimaging studies, the amygdala has been particularly associated with the long-term memory of emotional stimuli (Cahill et al., 1996; Hamann et al., 1999) which often follows a slower rate of forgetting (Phelps et al., 1998). For example, patients with amygdala damage show impaired memory for emotional items after a delayed memory test conducted one week later but performed similarly well to healthy controls in an immediate memory test administered an hour after learning (Claire, Sophie, Claudia, Philippe, & Eliane, 2016). It is thought that the reason for this pattern is due to the consolidation process in which the amygdala helps to facilitate the storage of emotional memories through its connections to other brain regions including the hippocampus.

Consolidation is a biochemical process which involves both hormonal and neural systems which work together to strengthen memories. When we experience an emotional event, our sympathetic nervous system is activated and subsequently releases certain hormones such as epinephrine. The release of these hormones in turn activate the noradrenergic system within the amygdala which then strengthens the synapses in the hippocampus (see synaptic tagging and capture; Frey & Morris, 1997, 1998). It is the activation of these systems that mediates the consolidation of long-term memories in other brain regions (see McGaugh, 2004a for a review).

1.3.3 Emotional enhancement of memory increases over time

However, the process of consolidation does not happen immediately. Instead, consolidation is a time-dependent process that can occur several hours after learning and can even continue for weeks and months after an event (see Roesler & McGaugh, 2010 for a discussion). This therefore explains the reason why differences are often found in the short and long-term effects of emotion on memory. For example, emotion has been shown to impair short-term processing (Kleinsmith & Kaplan, 1963) but has also shown beneficial effects on long-term retention (for a review see Yonelinas & Ritchey, 2015). In other words, a common finding is that a memorial advantage for emotionally arousing material often appears after a delay (Quevedo et al., 2003; Sharot, Verfaelli, & Yonelinas, 2007; Sharot & Yonelinas, 2008). This is evident in experiments that find greater memory performance for emotionally arousing stimuli in delayed memory tests but not immediate ones. For example, Sharot and Phelps (2004) showed participants an arousing or neutral word which was at the periphery of a central word that participants were asked to focus on. Memory for the peripheral words was then tested either immediately or after a 24 hour delay. Their results showed that while there was no memorial advantage for the arousing words in the immediate memory test, participants remembered the arousing words better than neutral words after 24 hours suggesting that experiencing emotional arousal promotes slower forgetting.

1.4 The Emotional Enhancement of Autobiographical Memories

Up to this point, I have mostly discussed evidence from scientific research conducted within the laboratory in which participants are presented with emotional images, sounds, narratives or films. While this type of research has significantly contributed to our wider understanding of how emotion affects our memory, it does not necessarily reflect the way in which we form emotional memories in the real-world. It is also the case that emotional arousal can facilitate memory for personal experiences that evoke emotion outside of the laboratory. These include autobiographical memories which concern the knowledge we hold about ourselves including memories for life events that we have experienced such as moving house or graduating school (i.e. personal episodic information).These episodic memories involve a sense of reliving a past event that often include sensory details (M. A. Conway, 2009) such as tastes and smells (Sutin & Robins, 2007) as well as emotional details and narratives. According to Bluck and colleagues (2005) the literature on autobiographical memories suggests that there are three theoretical functions of autobiographical memories: self, social and directive. Many researchers agree that autobiographical memories play a role in the development of our sense of self (Bluck & Alea, 2008) allowing us to maintain a form of identity (M. A. Conway, Singer, & Tagini, 2004) and that by sharing our autobiographical experiences, we are able to form social bonds (Bluck & Alea, 2011). Furthermore, autobiographical memories are also thought to help direct our future behaviour (Pillemer, 2003); by recalling past experiences, we are able to use past memories to problem-solve and predict future events. Across all of these theoretical functions, emotion has been found to play a critical role. For example, by recalling positive memories, we can increase our self-esteem and maintain a positive self-image (D'Argembeau & Van der Linden, 2008; Pasupathi, 2003) and by sharing positive memories with others, we can increase positive feelings and strengthen the social bond with whom we are sharing (Reis et al., 2010). Meanwhile, autobiographical memories can be used to help regulate emotion (Bluck et al., 2005) for example by recalling positive past experiences to counteract current negative mood (Josephson, 1996).

However, the emergence of autobiographical memory research was much slower than experimental memory research which emerged in the late 1800s. In fact, it was around one hundred years later, in the 1970s-1980s, when autobiographical memory research emerged as its own branch (Berntsen & Rubin, 2012). Though it took some time for autobiographical memory research to be accepted by the wider scientific community due to its theoretical and methodological challenges, it has since become a major standalone field of memory research.

A critical difference between autobiographical memory research and experimental memory research though concerns the methodology. Unlike memories for materials learnt within a laboratory-based setting, autobiographical memories rely on individuals reporting past personal events meaning that the accuracy of these memories is often hard to assess (Berntsen & Rubin, 2012). Many studies rely upon an individual’s personal account that is recalled at one time point that is weeks, months or years after the actual event has taken place. Therefore not only do these studies frequently lack an objective measure of memory shortly after the event takes place but they are also often limited by a single assessment of memory meaning that it is difficult to determine the consistency of the current memory to the initial memory and how it may have changed over time. However, some researchers have overcome these limitations by asking participants to keep a diary of events and then asking the participants to recall the information after a delay. This allows the researchers to have an objective measure of the memories as they were formed which they can then use to compare the recalled memories. Yet, even these studies still rely upon self-report measures meaning there is no control over what participants decide to include in their diaries in the first place.

Yet a shared similarity between memories formed in the laboratory and real-life autobiographical memories concerns the effects of emotion. Like laboratory-based memories, autobiographical memories also benefit from emotion. Early research that concentrated on autobiographical memories considered there to be a special mechanism that was responsible for this emotional memory enhancement. For example, in Brown and Kulik's seminal work (1977), they highlighted that even after many years since John F. Kennedy was assassinated, most people could recall specific details about where they were, who they were with and what they were doing when they found out. They argued that the reason why people could remember JFK's assassination with such vividness was due to the emotional significance of the event. Expanding upon the ''Now Print'' theory (Livingston, 1967), Brown and Kulik claimed that when we experience such a surprising event that elicits an emotional reaction, our brain activates the limbic system to permanently document the information, so that it can then be vividly and accurately recalled later on. In other words, they concluded that there was a special mechanism that allowed individuals to maintain these accurate, photograph-like "flashbulb memories", even after a prolonged passage of time.

While many researchers now acknowledge that emotional memories are actually less accurate than we initially believed them to be (e.g. Schmolck, Buffalo, & Squire, 2000) parts of Brown and Kulik's theory are still supported by more recent research. It is certainly true that novel or emotional events can increase the activity seen in the limbic system and that this can subsequently enhance memory for emotional items (for review see LaBar & Cabeza, 2006). However, more recent research acknowledges that emotional arousal does not enhance memory for absolutely everything but is instead associated with both impairing and enhancing effects. Nevertheless, these "flashbulb memories", though susceptible to inaccuracies and decay over time, especially within the first year following the event (Hirst et al., 2015), are still unique in that they are commonly associated with greater levels of phenomenological characteristics such as confidence (Hirst et al., 2009; Talarico & Rubin, 2007) and vividness which remain high, even a decade later (Hirst et al., 2015). Therefore while the initial researchers believed that flashbulb memories were formed based on a special memory mechanism, it is now widely accepted that the permanency of these memories is believed to depend on a number of factors such as surprise (Brown & Kulik, 1977; Páez et al., 2018), rehearsal (Berntsen & Thomsen, 2005; Breslin & Safer, 2011; Koppel, Brown, Stone, Coman, & Hirst, 2013), emotional intensity (Berntsen & Thomsen, 2005; Tekcan, 2001) and importance (Brown & Kulik, 1977; M. A. Conway et al., 1994) which are thought to be important in the encoding and then maintenance of the memory over time.

1.5 The Independent Effects of Valence on Memory

Up until this point, the effects of emotion on memory have been discussed in terms of arousal and the associated effects of stress hormones as well as the role of the amygdala. It is clear that there is substantial evidence to support the idea that emotional arousal has enhancing effects on memory. However, as previously mentioned, emotion, when defined using the Circumplex Model of Affect, is considered to be a two dimensional construct that also includes valence (Russell, 1980) therefore, it is equally important to understand the separable effects of valence. However, understanding the separate effects of valence on memory is often confounded by the fact that valence can also vary in arousal. In other words, it is often difficult to disentangle the separate effects of each. For example, in the study conducted by Cahill and colleagues (1996), the film clips that varied in valence were rated as significantly different in terms of arousal; a problem that is prevalent across a number of studies (Dewhurst & Parry, 2000; Pierce & Kensinger, 2011; Sharot, Delgado, & Phelps, 2004; Sharot et al., 2007). It is often the case that negative stimuli are more strongly associated with arousal than positive items are (Bradley, Codispoti, Sabatinelli, & Lang, 2001) suggesting that it could in fact be arousal that leads to memory enhancing effects and not valence per se.

Some researchers strongly argue that the emotional enhancement seen in memory is entirely attributable to arousal and not to valence (e.g. Bradley et al., 1992; Mather, 2007) since memory can be enhanced for both valences so long as there is a sufficient level of arousal. On the other hand, other researchers argue that valence can also have facilitative effects on memory but only when arousal is controlled for (Kensinger & Corkin, 2004; LaBar & Cabeza, 2006). In an attempt to understand the dissociable effects of valence and arousal on emotional memory, Adelman and Estes (2013) tested participants' memory for positive, negative and neutral words that varied in arousal and were controlled for in terms of lexical and semantic factors. As expected, they found that negative and positive items were remembered better than neutral ones and this was true regardless of arousal ratings. Interestingly, they failed to find independent effects of arousal or an interaction between arousal and valence. They therefore argued that their results support the idea that valence can have independent facilitative effects on memory.

Further evidence for the separable effects of valence and arousal on emotional processing comes from functional magnetic resonance imaging (fMRI) studies that have found different patterns of neural activation for valence. For example, it is widely found that highly arousing stimuli is associated with amygdala activity during encoding (Kensinger & Corkin, 2004; Mickley & Kensinger, 2008) meanwhile, in studies examining the independent effects of valence (after controlling for the effects of arousal) differences in brain activity are found based on valence (Mickley & Kensinger, 2008; Mickley Steinmetz & Kensinger, 2009). In one study conducted by Kensinger and colleagues (2006a), participants were presented with positive, negative and neutral images and words that were matched on arousal ratings whilst they were in the MRI scanner. Their results indicated that the ventrolateral prefrontal cortex (PFC) responded more to negative words and pictures than positive items, whereas activity in the medial PFC was greater for positive than negative items. These findings are consistent with other studies that have equally found that increased activation among lateral PFC regions are associated with negative stimuli while increased activation among medial PFC regions are associated with positive stimuli (e.g. Dolcos et al., 2004; O'Doherty, Rolls, Francis, Bowtell, & McGlone, 2001). Collectively therefore, the evidence would suggest that while it is widely known that arousal plays an important part in enhancing emotional memories, that valence equally plays an important role in emotional memories and should not be overlooked. Despite the aforementioned evidence however, the literature on the separable effects of positive and negative valence from arousal on memory is sparse and provides mixed results.

Another limitation of the literature discussed so far is that experiments that examine the effects of arousal do not always include positive stimuli as well (e.g. Adolphs et al., 2001; Anderson et al., 2006; Kensinger, Garoff-Eaton, et al., 2006; Kensinger et al., 2007a; Madan et al., 2012; Payne et al., 2007; Rimmele, Domes, Mathiak, & Hautzinger, 2003; Strange et al., 2003; Talmi & Moscovitch, 2004). Therefore, a lot of what we know regarding the effects of arousal is often specific to negative material. Yet, evidence from studies that examine both positive and negative emotion suggest that the effects of arousal on the amygdala may actually differ depending on the valence of the stimuli. For example, previous researchers have found that amygdala activity is greater for negative images when they are also high in arousal (Garavan, Pendergrass, Ross, Stein, & Risinger, 2001). Yet, in the same study, the pattern was not true for positive images. Instead, regardless of whether the positive images were high or low in arousal, the amygdala activation was comparable.

The idea that valence and arousal interact however, is not a new concept and many studies have found such patterns (Citron, Weekes, & Ferstl, 2014; Feng et al., 2012; Libkuman, Stabler, & Otani, 2004; Nielen et al., 2009; Waring & Kensinger, 2011). In another study, Steinmetz and colleagues (2010) examined the amygdala's connectivity to other areas within the emotional memory network and hypothesized that the effects of arousal on amygdala connectivity may differ depending on the valence. They predicted that the effect of arousal on the amygdala connectivity may be stronger for negative than for positive stimuli based on previous evidence that found the amygdala was essential for the processing of arousing negative images (e.g. Berntson, Bechara, Damasio, Tranel, & Cacioppo, 2007). In their study, whereby they showed participants positive, negative and neutral images whilst inside the MRI scanner, they found that for negative stimuli, arousal increased the strength of connectivity between the amygdala and areas of the inferior frontal gyrus and the middle occipital gyrus. However, the opposite pattern was found for positive stimuli which yielded a reduction in the strength between these areas. Furthermore, patients with amygdala damage show difficulty in re-experiencing negative events but do not show the same difficulty with positive ones (Buchanan, Tranel, & Adolphs, 2005a, 2005b; Claire et al., 2016). Therefore, collectively, the evidence would suggest that the relationship between emotional arousal and amygdala activation may vary depending on the valence.

1.5.1 The effects of positive and negative valence on episodic memory

When examining the differences between positive and negative emotion on emotional processing, the literature has highlighted several differences in both memory encoding (Kensinger, 2009b; Mickley & Kensinger, 2008; Mickley Steinmetz & Kensinger, 2009) and in recall and recognition (Kensinger, 2009b; Levine & Edelstein, 2009). Early research investigating the effects of positive and negative emotion on memory typically adopted a Freudian perspective and hypothesized that individuals were more likely to forget past negative experiences than they were positive ones. This particular approach still resonates with researchers today and is in concordance with more recent theories such as the Pollyanna principle (Matlin & Stang, 1978) and the fading affect bias (Walker, Skowronski, & Thompson, 2003); both of which hypothesize that negative memories fade more quickly over time compared to positive ones.

However, across many laboratory-based experiments, there seems to be a superior memory enhancing effect of negative emotion (Dewhurst & Parry, 2000; Keightley, Chiew, Anderson, & Grady, 2011; Kensinger et al., 2007a; Xie & Zhang, 2017) however, see Madan et al. (2019) for an exception and Chapter 1.2 for a discussion on the enhancing and impairing effects of emotion, particularly negative emotion, on memory. For example, participants sometimes show better memory for the visual details of negative pictures than for positive and neutral ones (Kensinger & Schacter, 2008 but see Adolph, Tranel & Buchanan, 2005; Burke, Heuer, & Reisberg, 1992; Denburg, Buchanan, Tranel & Adolphs, 2003) and negative items are more likely to be recalled than positive ones (e.g., Keightley et al., 2011). This is even evident when attention conditions are manipulated suggesting that positive and negative emotion may depend on different emotional processes. For example, in one study participants were presented with positive, negative and neutral images under full versus divided attention conditions (Talmi, Schimmack, Paterson, & Moscovitch, 2007). The researchers found that while memory performance for both positive and negative images was enhanced compared to neutral images, this was only true under the full attention condition. When attention was divided during encoding, memory for positive images was impaired. Some believe that the reason for this difference is because negative stimuli may be more deeply encoded compared to positive stimuli (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). However, it is worth highlighting that there are inconsistencies to this pattern too. As previously mentioned in Chapter 1.2, negative emotion has sometimes been found to impair memory for the visual details too, especially when more complex scenes are used (Adolphs et al., 2001; Denburg, Buchanan, Tranel, & Adolphs, 2003b).

There is support for the idea that the differences in memory due to valence arise because of the ways in which positive and negative emotion are initially processed. For example, the affect-as-information framework (Storbeck & Clore, 2005) suggests that negative emotion signals a problem whereas positive emotion signals safety. As a consequence, negative emotion requires bottom-up processing in which attention to the specific details of the event are prioritized which results in negative memories being recalled more accurately. Positive emotion on the other hand encourages top-down processing and relies more heavily on prior knowledge and scripts meaning that these memories are more prone to errors. A more recent model, known as the Negative Emotional Valence Enhances Recapitulation (NEVER) model (Bowen, Kark, & Kensinger, 2018) also suggests that memory is affected differently depending on the valence and importantly, even when arousal is controlled for. The model explains that unlike positive emotion, experiencing negative emotion increases the encoding of sensory detail which is supported by fMRI experiments that find that the successful encoding of negative stimuli is associated with increased activity in the visual cortex compared to positive emotion (Kensinger & Schacter, 2008; Mickley & Kensinger, 2008). As a consequence, the sensory details of a negative event are more likely to be incorporated into memory, meaning that these memories, when recalled, may be considered more vivid. Taken together, these two models suggest that memory for negative events may be superior to that of positive events given these differences in emotional processing which is in consistent with many laboratory-based findings.

1.5.2 The effects of positive and negative valence on autobiographical memory

However, when examining the effects of valence on autobiographical memories, the pattern of results is different to that frequently observed within the laboratory. Unlike negative autobiographical memories, positive memories are associated with greater levels of sensory detail , are recalled more frequently (Matlin & Stang, 1978) and retain their emotionality better than negative memories (Levine & Bluck, 2004; Walker et al., 2003). There have been several possible explanations for this including that positive events are more likely to be integrated into a perception of themselves since people's self-schemas are generally positive (Matlin & Stang, 1978). However, a limitation of assessing autobiographical memories is that it relies upon self-reported memories that are recalled weeks, months and sometimes even years after the event and often with no initial memory assessment to compare it to. Therefore, it is difficult to know whether positive autobiographical memories do in fact have a mnemonic advantage over negative autobiographical memories.

1.5.3 Positive versus negative flashbulb memories

Some researchers have overcome this issue and have investigated autobiographical memories for public events allowing them to verify certain details with factual evidence. Not only that, but these 'flashbulb memory' studies often obtain multiple memory accounts allowing them to examine how memories change over time. Many of these previous studies however have focused predominantly on negative public events such as the 9/11 terrorist attack (Curci & Luminet, 2006; Hirst et al., 2009; Kvavilashvili, Mirani, Schlagman, Foley,

& Kornbrot, 2009) or the deaths of well-known figures (Brown & Kulik, 1977; Day & Ross, 2014; Hornstein, Brown, & Mulligan, 2003). As a consequence, our understanding of the relationship between positive events and flashbulb memories is more limited.

Early reports suggested that valence yielded no significant differences in the how vividly they were remembered and what information could be recalled (i.e. where they were, what they were doing, how they heard of the event, what they did afterwards and how they and others felt; Scott & Ponsoda, 1996). Recent research also confirms that levels of vividness are similar for both positive and negative events (Berntsen & Thomsen, 2005; Breslin & Safer, 2011; Kensinger & Schacter, 2006a). However, results for other features of flashbulb memories, such as accuracy and confidence, are rather mixed. Some studies found that confidence (A. Bohn & Berntsen, 2007; Liu, Ying, & Luo, 2012; Talarico & Moore, 2012) and memory consistency (Liu, Ying & Luo, 2012; Talarico & Moore, 2012) are also similar for both positive and negative events. However, other researchers have found that positive and negative emotions are differently associated with confidence (Kensinger & Schacter, 2006a; Kraha & Boals, 2014), while others have found that positive emotion can actually lead to greater levels of inaccuracy (A. Bohn & Berntsen, 2007; Demiray & Freund, 2015; Kensinger & Schacter, 2006a; Levine & Bluck, 2004). Thus, it remains unclear whether memories for positive and negative events are associated with the same levels of consistency and confidence.

This confusing set of outcomes for memory consistency and confidence may be due to the significant methodological differences across the studies. For example, researchers often assessed memory for two separate events (one for each valence) that were qualitatively different (Koppel et al., 2013; Kraha & Boals, 2014); for example the positive event is often a personal one such as being accepted to college, while the negative event is a public event such as a natural disaster or a national tragedy like 9/11 (Kraha & Boals, 2014; Kraha, Talarico, & Boals, 2014; Liu et al., 2012). Therefore, it is difficult to know whether the differences in memory measures are due to the valence of the events or other confounds (e.g., public events often get more media attention than personal events).

To address this issue, other studies focused on memory for a single event and compared memory for the same event in those who found the event positive vs. those who found the event negative. However, the results from these studies are still mixed. For example, Kensinger and Schacter (2006) found that memory consistency was better among fans of a losing baseball team (negative event) than it was for the winning team (positive event) whereas Talarico and Moore (2012) found that fans of both the winning and losing teams were just as consistent. While Kensinger and Schacter (2006) found that participants who interpreted the event as positive, reported higher levels of confidence (despite higher levels of inconsistency), Talarico and Moore (2012) found no significant differences between the positive and negative group. Therefore, it is currently unclear whether positive and negative emotion modulates our autobiographical memories in the same way.

As such, one aim of the first empirical study (reported in Chapter 3) is to understand the role of valence on long-term autobiographical memories for a highly emotional, and to some, a highly surprising, political event. In this study, I not only consider the subjective measures of memory vividness and confidence but also the objective measure of memory consistency in order to determine whether valence has differing effects on these outcomes.

1.6 Interim Summary

To briefly summarise the literature that has been discussed so far, arousal is one dimension of emotion (when interpreted using Russel's Circumplex Model of Affect, 1980) that can direct attention and enhance subsequent memory. However, experiencing arousal does not necessarily guarantee highly accurate memories for everything that we are exposed to. Instead, it is now more generally accepted that arousal can have selective effects on what we remember. In other words, arousal may increase our memory for some things but does so at the expense of others. According to the ABC theory (Mather & Sutherland, 2011), this selective pattern depends on the priority of items and/or mental representations at the time. As such, high priority items, that are perhaps visually salient or in line with our top-down goals for example, are more likely to receive the attentional resources necessary to facilitate subsequent memory. As such, many researchers have proposed that arousal is the key dimension of emotion that leads to the emotional enhancement seen in memory (e.g. Bradley et al., 1992; Mather, 2007). However, the second dimension of emotion; valence, is considered by some to have independent facilitative effects on memory that are separate from arousal (Adelman & Estes, 2013). These independent effects of valence are more prevalent when comparing the findings from laboratory-based studies and the findings from autobiographical memory. Whereas negative emotion often has a mnemonic advantage on memories formed within the laboratory, positive emotion seems to have the advantage when examining autobiographical memories. In order to explore this differential pattern further, this thesis considers the effects of valence on long-term memories formed within and outside of the laboratory.

2. Chapter 2: The Effects of Aging on Memory

Most of what has been discussed so far has included research that has predominantly investigated the effects of emotion on memory using younger, healthy adults with little consideration being given to the added effects of chronological age on emotional memory. Therefore, although certain patterns and trends on the effects of emotion on memory were highlighted in the previous chapter, it is important to understand how these findings may differ among an aged population. The current chapter therefore discusses the aging and emotional memory literature to highlight some of the consistencies and inconsistencies of what has been covered so far.

It is inevitable that as we grow old we experience declines in both our physical and mental functioning. Our ability to remember things, the speed at which we are able to process information, our attention span and our ability to problem solve are just a few examples of our cognitive abilities that are affected by aging (Cabeza, Nyberg, & Park, 2005). In addition, many perceive old age as an isolating and lonely time of life that is coupled with an increased prevalence of ill-health, bereavement and increased dependency. However despite these age-related cognitive declines and these negative perceptions of aging, older adults frequently report better emotional well-being compared to younger adults (Carstensen, Scheibe, Ram, Ersner-hershfield, & Brooks, 2011) and still benefit from emotional memory enhancement (Kensinger, 2009) suggesting that emotional processing is preserved and possibly even enhanced in aging. Therefore the life-span trajectories of emotional processing and that of cognition seem to follow opposing patterns.

These diverging developmental trends are particularly interesting given what we know about the interactions between emotion and cognition. For example, it is well documented that we can control our emotions through the utilisation of executive functions

(Ochsner & Gross, 2005; Richards & Gross, 2000) and that when such prefrontal areas responsible for executive functioning are damaged, the ability to exert control over our emotions is weakened. Likewise, there is substantial research showing how our emotions can influence our executive functions such as our attention and memory (Dolcos et al., 2011; Pessoa, 2009; Vuilleumier & Huang, 2009).

2.1 The Effects of Aging on Episodic Memory

In terms of cognitive decline, our episodic memory is considered to be particularly vulnerable to the effects of aging and is thought to be a consequence of neural changes in grey matter volume and functional changes in the medial temporal regions (Nyberg, Lövdén, Riklund, Lindenberger, & Bäckman, 2012; Rajah, Maillet, & Grady, 2015). According to some research, the decline in episodic memory performance is evident as early as middle-age when individuals begin to struggle to remember names, faces and important dates like birthdays. However, evidence from longitudinal research, which tracks memory performance in the same individuals over time, suggests that memory deficits in episodic memory are most notable after the age of 60 (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). This pattern is paralleled by neural changes in the areas of the brain known to be important in the formation of episodic memories, notably the medial temporal lobe, the hippocampus and the prefrontal cortex. It is these same areas within younger adults which have been implicated in the successful encoding of information (Blumenfeld & Ranganath, 2007). Therefore, it seems reasonable to assume that memory may be impaired with aging because of neural changes in the brain.

When examining episodic memory between younger and older adults, younger adults often show better memory performance in free and cued recall as well as recognition (e.g., Hess, 2005) and more specifically when the binding of information is required (e.g. Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000). At the same time, older adults typically report increased memory complaints (Mol, van Boxtel, Willems, & Jolles, 2006) and experience difficulties in remembering people's names or to take medication. Therefore, based on these findings, it would be logical to assume that emotional memory would suffer the same fate.

However, the memory benefit for emotional information is in fact preserved in older adults (Charles, Mather, & Carstensen, 2003; Mather, 2004; St. Jacques & Levine, 2007) who frequently show similar memory-related advantages for emotionally arousing stimuli to younger adults (e.g. Murphy & Isaacowitz, 2008) and typically remember emotional stimuli better than neutral stimuli (Kensinger, 2009a; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). However, this is not to say that the effects of emotion on memory follow the same exact pattern in younger and older adults. In fact, evidence would suggest that there are in fact significant differences in the effects of emotion on memory between younger and older adults, especially concerning the effects of valence.

2.2 The Effects of Aging on the Emotional Enhancement of Autobiographical Memories

When examining age-related differences in the formation and maintenance of memories for an emotional event, the literature provides evidence both for and against age-related differences and the flashbulb memory literature is no exception. As previously mentioned, flashbulb memories are a unique type of autobiographical memory for past events that are typically accompanied by emotional significance. Early work by Cohen and colleagues (1994) investigated younger (aged between 18 and 55) and older participants' (aged between 64 and 84) memories for Margaret Thatcher's resignation shortly after the event (2 weeks) and again 11 months later as it was deemed to be a highly surprising public event that was of national importance. The researchers found that while short-term flashbulb memories were comparable between the young and the old, less than half of the older adults met criteria for having a flashbulb memory following a delay, compared to 92% of younger adults. They therefore concluded that their results indicated an age-related impairment for the long-term memory of events that could reflect reduced frontal lobe functioning in the elderly. However, they also acknowledged that Thatcher's resignation was rated as only moderately arousing by older adults who were also less surprised by the news too. Therefore, it is possible that the age-related deficit could simply reflect a difference between the two groups in the initial arousal levels generated by the event. Nevertheless, subsequent studies have also found age-related differences, in which older adults often show poorer memory compared to their younger counterparts (e.g. Kensinger, Krendl, & Corkin, 2006; Tekcan & Peynircioğlu, 2002). Since some researchers also consider flashbulb memories to be similar to source memories as both concern the details of when, where and from whom a person learned the information about an event (Davidson, Cook, & Glisky, 2006), it seems plausible that flashbulb memories would decline with age just as source memories do (for a review see Prull, Gabrieli, & Bunge, 2000).

However, Davidson & Glisky (2002) assessed flashbulb memories among younger and older adults regarding the deaths of Princess Diana and Mother Teresa and found that older adults were just as likely to recall the "source information" (i.e. where they were, when they learned about the news and how they found out), compared to younger adults. A subsequent paper by the same research group assessed flashbulb memories among younger and older adults following the 9/11 terrorist attack (Davidson et al., 2006). They obtained memories from participants between 3 and 21 days after and then again after one year (between 11 and 13 months). At each time point, participants were asked the same series of questions and initial and delayed memories were compared and rated by two naïve judges using Neisser and Harsch's "0, 1 or 2" coding system. Once again, their results indicated no age group differences. Collectively, these findings, from the two aforementioned experiments, are more consistent with a collection of studies that fail to find significant age-related differences in flashbulb memories (e.g. A. R. A. Conway, Skitka, Hemmerich, &

Kershaw, 2009; Kvavilashvili, Mirani, Schlagman, Erskine, & Kornbrot, 2010; D. B. Wright, Gaskell, & O'Muircheartaigh, 1998).

More recently, a meta-analysis specifically examining age-related differences in flashbulb memories attempted to synthesize the current findings to determine whether flashbulb memories were susceptible to age-related declines like those seen for general recall (Danckert & Craik, 2013) and recognition memory (Fraundorf, Hourihan, Peters, & Benjamin, 2019). The meta-analysis included 16 independent studies from 15 separate manuscripts that had previously examined flashbulb memories between younger adults whose average age was below 40 and older adults whose average age was above 60 (Kopp, Sockol, & Multhaup, 2020). The results indicated a small-to-moderate age-related impairment in flashbulb memory scores. In other words, older adults were less likely than younger adults to meet criteria for having a flashbulb memory for the studied events. They further found that older adults were overall less consistent in their flashbulb memories over time compared to younger adults. However, the authors emphasize the importance of interpreting the latter finding with caution since fewer studies were able to be included in this analysis. Overall though, their findings suggest that there are age-related impairments in flashbulb memories which is consistent with findings in more controlled, laboratory-based settings.

However, a notable limitation of the meta-analysis in addition to the small number of studies included, is that most of the studies examined flashbulb memories for a negative event such as the deaths of notable figures such as President John F. Kennedy (Yarmey & Bull, 1978), Mother Teresa (Davidson et al., 2006) and Princess Diana (Kvavilashvili, Mirani, Schlagman, Wellsted, & Kornbrot, 2009) as well as the September 11th terrorist attack (Davidson et al., 2006; Denver, Lane, & Cherry, 2010; Gerdy, Multhaup, & Ivey, 2007; Kvavilashvili, Mirani, Schlagman, Wellsted, et al., 2009) and other national disasters

(Kensinger, Krendl, et al., 2006; Otani et al., 2005). Therefore, their findings of age-related deficits could be specific to negative events.

This lack of inclusion of positive events reflects a wider shortcoming of the flashbulb memory literature as often flashbulb memory studies concern negative rather than positive events. This is an important limitation to consider when interpreting age-related differences given there is a large body of research which demonstrates valence specific effects in learning and memory among younger and older adults. That is, when we are younger, we demonstrate a strong negativity bias in which we attend to and remember more negative over positive information (Baumeister et al., 2001). Believed to be an adaptive function relevant to survival, this "negativity bias" is so reliable that some consider it to be an essential element of human behaviour (Carstensen & DeLiema, 2018) which is even evident in early childhood (LoBue, 2009; Vaish, Grossmann, & Woodward, 2008). However, with advanced aging, this "negativity bias" is seemingly weakened and is replaced with a bias for positive information. In fact, older adults frequently demonstrate a preference for positive over negative information in attention and memory (Carstensen & Mikels, 2005; Mather & Carstensen, 2005). In other words, there appears to be a shift in our emotional memory biases as we age (Ack Baraly, Morand, Fusca, Davidson, & Hot, 2019) in which we experience an increased preference for positive over negative information; otherwise known as the *positivity effect*.

2.3 The Interaction between Valence and Aging on Memory and Well-Being

2.3.1 The Positivity Effect

While one might assume that aging would impair emotional memory, research actually highlights that there is a shift in what emotional information younger and older adults subsequently remember. An interesting concept to arise from studies examining the differences in emotional memory between younger and older adults is the positivity effect. The positivity effect is a robust finding that is evident across both attention and memory (see

Reed, Chan, & Mikels, 2014 for a review) which frequently shows that positive over negative information is preferred by older adults. For example, older adults have been found to spend less time attending to negative images (Isaacowitz, Wadlinger, Goren, & Wilson, 2006) and also show a preference in both attention and memory to positive over negative information (Charles, Mather & Carstensen, 2003). Meanwhile, in studies investigating the detection of emotional faces, older adults were found to have greater difficulty in recognizing negative emotions such as anger, fear and sadness but did not have the same difficulty with detecting positive facial expressions of happiness and surprise (Calder et al., 2003; Sullivan & Ruffman, 2004). However, the results from a meta-analysis specifically looking at the preferences of emotional information in younger and older adults suggested that this pattern was the result of older adults exhibiting reduced attention to negative information as opposed to an increase in attention to positive information compared to younger adults (Murphy & Isaacowitz, 2008).

Indeed, a reduced preference for negative information among older adults compared to younger adults is one way researchers have defined the positivity effect. Therefore, while the definitions of the positivity effect can vary across studies, it generally refers to patterns in attention and/or memory in which positive information is favoured, whether that is relative to negative or neutral information. In Reed et al.'s meta-analyses, they define the positivity effect as an age-related trend in which older adults appear to favour positive over negative information relative to younger adults in domains like attention (Isaacowitz et al., 2006; Kappes, Streubel, Droste, & Folta-Schoofs, 2017; Sasse, Gamer, Büchel, & Brassen, 2014) and memory (Joubert, Davidson, & Chainay, 2018; Kan, Garrison, Drummey, Emmert, & Rogers, 2018; Kennedy, Mather, & Carstensen, 2004). For some studies, the positivity effect is specifically when positive information is remembered better than negative information (e.g. Carstensen & Mikels, 2005; Mather & Carstensen, 2005) but Reed and colleagues

(2014) highlight that it can also refer to occasions whereby there is a reduced preference for negative information too. There are many studies that provide evidence for the positivity effect including those that show how older adults exhibit an attentional preferences to positive and away from negative images (Allard & Kensinger, 2014; Isaacowitz et al., 2006) and how older adults take longer to detect a target when it is preceded by a negative rather than a positive image (Mather & Carstensen, 2003).

2.3.2 Emotional well-being in aging

In addition to these findings within the laboratory, there is also extensive work which suggests that experienced emotions changes with age too (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Charles, Reynolds, & Gatz, 2001; Mroczek & Kolarz, 1998). More specifically, emotions experienced in daily life seem to reflect a similar pattern to that evidenced within the laboratory i.e. older adults frequently report greater levels of positive affect and lower levels of negative affect (Carstensen, Turan, et al., 2011; Stone, Schwartz, Broderick, & Deaton, 2010). More broadly, the literature suggests that compared to younger adults, older adults experience better emotional well-being (Carstensen & DeLiema, 2018).

Emotional well-being is considered to be the subjective experience of emotions and can be defined in terms of happiness, life satisfaction or the degree to which an individual reports negative and positive emotion (Charles & Carstensen, 2010). When studies have examined the relationship between chronological age and emotional well-being, they have found a U-shaped pattern in which emotional well-being is lowest for middle-aged adults aged between 45-55 years (Blanchflower & Oswald, 2008; Steptoe, Deaton, & Stone, 2015), however, with increased aging, well-being appears to improve until people reach their eighties (Mroczek & Spiro, 2003). Similarly, other studies have found that ratings of overall happiness and life satisfaction are greatest among individuals in their sixties and seventies (Steptoe et al., 2015; Stone et al., 2010). Therefore, just as emotional processing is preserved among older adults when tested within the laboratory, so too is experienced emotion in daily life.

On the surface, this pattern may seem surprising especially since aging is marked by an increase in losses and a reduction in gains (M. M. Baltes, 1995). For example, older adults frequently lose their autonomy and become dependent on others for certain tasks. Likewise, due to an increase likelihood of experiencing physical declines, the ability to undertake some forms of physical activity are also reduced. Consequently this means that certain social activities are abandoned, leading to fewer opportunities for social engagement which is considered to be beneficial for emotional well-being (Charles & Carstensen, 2010). Nevertheless, despite all this, older adults' maintain good levels of emotional well-being even though there is arguably a disproportionate balance of losses versus gains. This phenomena is commonly referred to as the well-being paradox (P. B. Baltes & Baltes, 1990) or the paradox of aging (Mather, 2012) and reflects the juxtaposition between the decreases in health and cognitive abilities and the increase in reported positive affect or increased emotional well-being in aging.

2.3.3 Socioemotional Selectivity Theory

One particular theory that is thought to explain both the positivity effect seen in attention and memory and the increase in emotional well-being in daily life among older adults is the Socioemotional Selectivity Theory (SST; Carstensen, Isaacowitz, & Charles, 1999). The SST is a life-span theory of motivation which proposes how our goals change as a function of our future time perception. Before explaining the SST further however, it is important to note that the original theory did not specifically concentrate on why older adults showed a preference to positive over negative stimuli in attention and memory but rather on why older adults frequently exhibited differences in goal preferences, particularly in relation to social and emotional goals.

According to the theory, one way in which older adults may achieve higher levels of life satisfaction and/or better emotional well-being in daily life is through the prioritisation of social- and emotion-related goals. An important tenant of the SST is that these goals are thought to become more salient with age since older adults view their time left in life as less expansive (Carstensen et al., 1999). In other words, the perception of time we have left in our life is thought to encourage older adults to focus on the present – rather than the future (Barber, Opitz, Martins, Sakaki, & Mather, 2016). This motivational shift leads older adults to favour emotional stability and positive experiences over increasing knowledge or wealth (Carstensen, Isaacowitz, & Charles, 1999) and allows them to concentrate more on maximising positive affect. Therefore, rather than concentrating on long-term goals of knowledge acquisition, making new friends or planning a career path which may be beneficial in future years, older adults focus on goals that are more emotionally meaningful and person-focused that can be obtained in the short-term. As such, compared to younger adults, older adults may make decisions and behave in ways that are more likely to lead to positive outcomes such as avoiding stressful situations or spending time with individuals with whom they have an emotionally meaningful relationship. The SST therefore helps to explain why older adults frequently report greater emotional well-being (Carstensen, Turan, et al., 2011) and experience fewer daily stressors than younger adults (Brose, Scheibe, & Schmiedek, 2013) and why older adults are often more satisfied with their social networks than younger adults are (Carstensen, 1992).

2.3.4 The Socioemotional Selectivity Theory and the role of future time perspective

Much of the early support for the SST comes from studies investigating social judgements and goal attainment (Carstensen et al., 1999) and found that when time horizons are manipulated, to be more or less expansive, then social judgements and goal selection can be influenced. For example, in early work by Fung et al., (1999), younger and older adults' biases for familiar versus unfamiliar social partners was examined. The assumption being that older adults, due to their perception of limited time left in life, would choose emotionally meaningful, close social partners whereas younger adults would not be expected to demonstrate this bias. Confirming this prediction, their results showed that when the younger adults were asked to consider their time with their current social circle as coming to an end due to a hypothetical move, their choice of social goals changed to be more similar to that of older adults. In other words, they chose familiar social partners. Likewise, older adults in the same study were asked to imagine that they could live for an additional 20 years due to a medical breakthrough. This time, their choice of social goals was more similar to that expected from younger adults – rather than choosing to spend time with familiar partners, they chose to spend more time with unfamiliar social partners.

Since this study, several other researchers have found support for this time horizon manipulation effect and not just in terms of partner preferences. In another study, involving 480 adults aged between 20 and 90, participants were asked to complete a partner preference task and a social goal task to examine how a more or less expansive future time perspective would influence goal prioritisation. In the social goal task, participants were given cards with descriptions of different goals and plans and were asked to organise the cards into piles based on how important they personally deemed each goal and plan to be. For individuals who perceived their time to be more limited, goals that were emotionally meaningful were prioritised whereas for those who perceived their time to be more expansive, goals relating to social acceptance and autonomy were prioritised.

Taken together, these findings suggest that the shift in time perspective is critical in determining what goals are prioritised. For older adults, a less expansive future time perspective appears to influence decisions and behaviour that result in more immediate positive outcomes. As such, when older adults are presented with emotional information within a laboratory setting, they are thought to process information in such a way that maximises positive affect, possibly through emotion regulation efforts (Mather, 2012; Mather & Carstensen, 2005). For example, when older adults are presented with happy, angry and sad faces, they are more likely to attend to the positive faces and ignore the negative ones (Isaacowitz et al., 2006; Mather & Carstensen, 2003). Moreover, similar patterns have been evidenced in memory performance in which older adults recall more positive than negative information compared to younger adults (Charles et al., 2003; Mather & Carstensen, 2003). Therefore, it could be argued that the positivity effect and increased emotional well-being seen in older adults is a consequence of them allocating more resources to regulating their emotions (Mather, 2012; Mather & Carstensen, 2005). In summary then, SST seems to account not only for the positivity effects seen in the laboratory but also experienced emotions in daily life.

However, recent studies investigating age-related differences in emotional well-being and using the theoretical assumptions made by the SST to interpret their findings, have found that a more limited future time perspective is not always associated with better emotional well-being (e.g. L. Bohn, Kwong See, & Fung, 2016; Demiray & Bluck, 2014; Kotter-Grühn & Smith, 2011). In fact, several studies conclude that a more limited future time perspective is associated with lower levels of psychological well-being (Demiray & Bluck, 2014; Grühn, Sharifian, & Chu, 2016) and can also predict a decrease in well-being over time (Kotter-Grühn & Smith, 2011). Moreover, the literature examining time horizons on emotional memory is much sparser and the limited findings also provide a mixed picture. While some studies offer support for the SST's predictions and find that a more limited future time perspective is associated with the positivity effect in memory (Barber et al., 2016; Kennedy et al., 2004), others fail to find support for this pattern (L. Bohn et al., 2016; Kan et al., 2018). As such, there is growing scepticism about whether future time perspective is the critical component which leads older adults to demonstrate age-related differences in emotional attention and memory as well as well-being. Consequently, some researchers have considered whether the SST is comprehensive enough to explain all age-related differences in emotional processing.

2.3.5 The Aging-Brain Model

Importantly, the SST is not the only theory to explain the positivity effect. According to the aging brain model (Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011), the positivity effect arises due to an age-related neural decline which results in an attenuated amygdala activation to negative, but not positive, stimuli. These age-related declines seen in the amygdala selectively weaken the emotional arousal of negative stimuli and as a consequence, reduce the memorial advantage of negative stimuli. Therefore, the model posits that positivity effect, in which positive information is remembered better over negative information, is a consequence of negative stimuli being less arousing than positive information and therefore is less likely to be remembered.

This model is supported by a number of studies that have found a linear relationship between reductions in amygdala volume and chronological age (Mu, Xie, Wen, Weng, & Shuyun, 1999; C. I. Wright, Wedig, Williams, Rauch, & Albert, 2006; Zimmerman et al., 2006) suggesting that the amygdala is susceptible to age-related neural decline. Likewise, when the amygdala is damaged it can cause individuals to struggle to remember negatively arousing past events but does not have the same detrimental effect on the ability to recall past positive events (Buchanan, Etzel, Adolphs, & Tranel, 2006). Moreover, Cacioppo and colleagues provide evidence from a lesion study which supports the selective impairment for negative but not positive information (Cacioppo et al., 2011). In the study, the affective ratings from six amygdala/anterior temporal lesion patients were compared to those from a control group. While both groups showed similar levels of arousal ratings for positive images, the arousal ratings for negative images were significantly lower in the lesion group than the control group. Similarly, Mather et al. (2004) showed younger and older adults negative, positive and neutral images and found greater amygdala activation to positive than negative pictures in older participants but not within younger participants which could be interpreted as a weakened amygdala response to negative images.

Therefore, in line with the predictions of the aging brain model, older adults who show the positivity effect should also show impaired emotional processing for negative but persevered processing for positive stimuli in other tasks than memory. However, there is some evidence to refute this claim. Firstly, some studies demonstrate that the amygdala is relatively preserved with aging (Brabec et al., 2010) and there is also evidence that older adults experience similar levels of emotional arousal, regardless of valence, as shown by skin conductance responses to emotionally arousing stimuli (Denburg et al., 2003b). Moreover, they sometimes even provide higher arousal ratings than younger adults (Gavazzeni, Wiens, & Fischer, 2008; Grühn & Scheibe, 2008) indicating that they still maintain the ability to detect arousing stimuli. Furthermore, there is evidence that the acquisition of conditioned fear is also preserved in older adults (LaBar, Cook, Torpey, & Welsh-Bohmer, 2004; Sakaki, Raw, Findlay, & Thottam, 2019). In other words, older adults are still able to learn the association between a neutral, conditioned stimulus (CS) and an aversive or threatening stimulus (US) such as an electric shock or a burst of white noise, as are commonly used in fear-conditioning studies. Importantly, the acquisition of conditioned fear in both humans and animals, is dependent upon the amygdala (Büchel & Dolan, 2000; Cahill & McGaugh, 1998; LeDoux, 1995) so if the positivity effect arises due to attenuated amygdala activity specifically to negative information, then one would expect older adults to show weakened fear acquisition but this is not necessarily the case. Therefore, while it is true that the positivity effects are sometimes accompanied by a greater involvement of the amygdala during the processing of positive compared to negative information (or a reduction to negative compared to positive information) in older adults in comparison to young adults (Mather et al., 2004), it does not necessarily reflect a loss of amygdala function specifically to negative information.

Nevertheless, both the SST and the aging brain model predict that amygdala activation to negative stimuli, compared to positive stimuli, will be weakened. The difference between the two is that the SST predicts that the reason for this reduction is due to older adults focusing more on socio-emotional goals and the possibility that older adults are engaging in emotion regulation strategies to increase attention to positive but not negative stimuli. Therefore one aim of this thesis will be to test the predictions of the SST and aging brain model by examining the age-related differences in neural responses to emotional stimuli.

2.3.6 Cognitive Control Model

If the positivity effect arises due to older adults concentrating more on positive information and ignoring negative information, possibly through emotion regulation techniques, then this is likely to require top-down control (Mather & Carstensen, 2005; Reed & Carstensen, 2012; Sasse et al., 2014) which would allow them to re-direct their attention away from negative and towards positive information. Some researchers have thus extended on the SST to consider the role of cognitive control in explaining the positivity effect (Kryla-Lighthall & Mather, 2009; Mather & Knight, 2005; Nashiro, Sakaki, & Mather, 2012). According to the model, healthy aging is accompanied by a shift in the allocation of cognitive resources which allows them to pursue their short-term emotional goals. However, since maintaining goals is a critical aspect of cognitive control that is necessary for successful performance (Braver, Cohen, & Barch, 2002; Paxton, Barch, Racine, & Braver, 2008), the shift in goal prioritisation to concentrate more on positive information is likely to depend upon an individual's cognitive capacity. This prediction is supported by evidence that shows that the positivity effect in older adults is more pronounced in those who have higher scores in tests of executive functioning (or cognitive control) (Mather & Knight, 2005). Moreover, findings from a recent meta-analysis (Reed et al., 2014) indicated that the positivity effect was stronger when the processing of information was unconstrained. In other words, when older adults are allowed to process the information naturally and have full access to cognitive resources, rather than being influenced by experimental instructions such as asking them to judge each stimulus or to explicitly remember it, then the positivity effect is more pronounced. When experiments have manipulated the availability of cognitive resources through means such as dividing attention, the positivity effect is weakened. For example, Joubert et al., (2018) presented participants with pictures under full attention or divided attention conditions with the expectation that if the positivity effect was dependent upon cognitive control then under divided attention conditions, the positivity effect would be weakened or eliminated completely. Consistent with their hypothesis, they found that older adults showed greater memory for positive images compared to negative and neutral ones but only under full attention conditions. Therefore, the evidence would suggest that the positivity effect *is* dependent upon cognitive control.

Some researchers consider cognitive control to be a relatively slow process that occurs over time (Hutchison & Morton, 2016) whereas other researchers consider there to be two separate processes of cognitive control that vary in their time-course. According to the Dual Mechanisms of Control Framework (DMC: Braver, 2012) proactive control is a slower top-down process that enables the maintenance of goal-relevant information, whereas reactive control is a quicker bottom-up mode that is utilized to update current task goals. When looking specifically at the evidence from eye-tracking studies examining the positivity effect, the results suggest that the positivity effect does not occur early on in the time-course but becomes more prevalent after a delay (Mather & Knight, 2005). For example, older adults shift their gaze away from negative faces expressing anger or sadness and towards faces with positive emotions such as happiness but do so late after stimulus onset (Isaacowitz et al., 2006). Results such as these suggest that older adults may be relying upon the proactive control mode when processing emotional stimuli. This fits with the prediction of cognitive control extension of the SST in that emotion regulation goals are more chronically activated in the elderly than in the young. However, according to the DMC framework, proactive control is more likely to be impaired in the elderly than reactive control, though the framework does not specifically consider cognitive control in the context of emotion. Therefore, it may be the case that the positivity effect is the consequence of aged individuals using controlled emotional processing to concentrate more on positive than negative information. However, since this general mode of cognitive control is impaired in the elderly, they may require a longer period of time compared to younger adults in order to implement such top-down cognitive control.

However, to date, only a handful of studies have considered the temporal aspect of the positivity effect and most that do have either used eye-tracking techniques (Isaacowitz, Allard, Murphy, & Schlangel, 2009; Isaacowitz et al., 2006) or electroencephalographic (EEG) methods to measure event-related potentials (Kisley, Wood, & Burrows, 2007). Critically, even less have explicitly tested this hypothesis by examining the temporal changes in neural activation during emotional processing between younger and older adults (but see Allard & Kensinger, 2014; Roalf, Pruis, Stevens, & Janowsky, 2011). Therefore, one aim of study 2 is to investigate age-related differences in the time course of neural activation during emotional processing.

2.4 Age-Related Differences in Neural Activation to Positive and Negative Emotion

Consistent with the behavioural findings previously discussed in which older adults frequently demonstrate a different pattern in emotional memory to younger adults, it is perhaps not surprising to learn that the engagement of the emotional network seems to differ with age too (e.g. Gunning-Dixon et al., 2003). Early studies investigating age-related differences in emotion recognition concluded that older adults exhibited age-related deficits, particularly in the ability to identify negative facial expressions (Phillips, MacLean, & Allen, 2002; Sullivan & Ruffman, 2004; Suzuki, Hoshino, Shigemasu, & Kawamura, 2007) leading them to believe that this pattern was likely the consequence of amygdala degradation (Sullivan & Ruffman, 2004). Indeed, a common finding within the functional magnetic resonance imaging literature supported the pattern of reduced amygdala activity during emotional processing in aging, particularly to negative stimuli (Gunning-Dixon et al., 2003; Mather et al., 2004; Tessitore et al., 2005). However, as previously mentioned, while some researchers have considered this reduction in amygdala activation in older adults to reflect anatomical and functional decline (e.g. Malykhin, Bouchard, Camicioli, & Coupland, 2008), there is also evidence to suggest otherwise (Good et al., 2001; Grieve, Clark, Williams, Peduto, & Gordon, 2005). In fact, when comparing volumetric decline of brain areas, the amygdala shows less of a decline than most other regions (Allen, Bruss, Brown, & Damasio, 2005). Moreover, there is also evidence to suggest that the amygdala remains just as responsive to fearful faces in the elderly as it does in younger people (C. I. Wright et al., 2006).

Besides, when looking beyond the amygdala during emotional processing, research has also identified age-related differences in the prefrontal regions too. For example, compared to younger adults, older adults recruit prefrontal regions to a greater extent when processing emotions (Gunning-Dixon et al., 2003; Tessitore et al., 2005). In fact, age-related differences in emotional processing are frequently characterized by attenuated amygdala activity and increased prefrontal activity (e.g. Leclerc & Kensinger, 2008; St Jacques, Dolcos, & Cabeza, 2010). For example, in one study, Williams and colleagues (Williams et al., 2006) examined event-related potentials and fMRI activation to investigate the brain mechanisms that underlie emotional processing in advanced aging. They found that when older adults were presented with fearful faces, they showed increased mPFC activity and a reduction in amygdala activity. Patterns such as these are consistent with the Posterior-Anterior Shift in Ageing (PASA) model (Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008) whereby older adults typically exhibit reduced posterior brain activity and increases in prefrontal activity during cognitive tasks. Such patterns are thought to reflect a functional compensatory mechanism and while the PASA model derives from cognitive tasks such as episodic memory retrieval and visual perception, similar patterns have also been evidenced in emotional processing tasks too (Roalf et al., 2011; St. Jacques, Dolcos, & Cabeza, 2009). Similar to the PASA model, the frontoamygdalar age-related differences in emotion (FADE: St. Jacques, Bessette-Symons, & Cabeza, 2009) model also highlights the age-related differences in prefrontal regions and considers that the increases in prefrontal activity during emotional processing tasks may reflect compensatory mechanisms, self-referential processing or indeed emotion regulation.

The interpretation that this pattern of activation may reflect emotion regulation, is in line with the cognitive control extension of the SST which predicts that one way older adults are able to exhibit positivity effects is through controlled emotional processing which is dependent upon the engagement of prefrontal regions. Indeed, the cognitive control network of the brain comprises of several regions located within the prefrontal cortex (PFC) including the medial PFC (mPFC) and the anterior cingulate cortex (ACC). These regions work together with other brain regions to facilitate cognitive functions such as attention, working memory and planning (Niendam et al., 2012). Importantly however, the ventromedial PFC (vmPFC) is directly and anatomically connected to the amygdala (Ray & Zald, 2012) and is thought to facilitate the processing of emotional stimuli. In fact, the vmPFC features highly in studies investigating emotion regulation (see M. J. Kim et al., 2011 for a review) which frequently find an inverse coupling in activity between the vmPFC and the amygdala (Ochsner, Bunge, Gross, & Gabrieli, 2002; Urry et al., 2006), thought to reflect down-regulation (Phelps, Delgado, Nearing, & LeDoux, 2004 but see Buhle et al., 2014; Morawetz et al., 2017). For example, when participants are asked to weaken their emotional responses to negative images and to interpret them as less threatening, vmPFC activation increases (Delgado, Nearing, Ledoux, & Phelps, 2008) and amygdala activation decreases (Urry et al., 2006). As such, the vmPFC is thought to inhibit and/or regulate activity of the amygdala. This theory is substantiated by lesion studies in which patients with vmPFC damage show elevated levels of amygdala activity to negative images when compared with healthy controls (Motzkin et al., 2015). However, the findings from more recent meta-analyses do not support the idea that the vmPFC is commonly engaged during the down regulation of emotion (Buhle et al., 2013; Morawetz, Bode, Derntl, & Heekeren, 2017) and therefore cast some doubt over whether this region is critical during cognitive reappraisal.

That being said, in a meta-analysis examining concurrent amygdala and vmPFC activity during emotional processing, studies involving the down-regulation of negative emotion were more likely to report increased vmPFC activity and decreased amygdala activity however, for studies involving the passive viewing of negative stimuli around 68% reported vmPFC activity and increased amygdala activity (Yang, Tsai, & Li, 2020). These findings suggest that, in healthy younger adults, during the down-regulation of negative emotion, the vmPFC modulates amygdala activity. Taken together these results suggest that the vmPFC is critical in the regulation of amygdala activity and is particularly important for emotion regulation efforts that involve the down-regulation of negative emotion. Interestingly, older adults show greater dorsolateral PFC (dlPFC) activity for aversive stimuli compared to younger adults suggesting that they also rely on the same prefrontal regions as younger adults, but do so to a greater extent when downregulating negative affect. With this in mind, it is then plausible to assume that the positivity effect may be a consequence of older adults engaging in the down-regulation of negative affect. If this is the case, then in line with the cognitive control extension of the SST, one may expect the positivity effect to manifest as reduced amygdala activity to negative information and increased activity in the vmPFC. Therefore, study 2 will concentrate on neural activity in the amygdala, vmPFC and pgACC in order to investigate any age-related differences.

2.5 Current Study

As has been discussed in the Introduction, emotional events are better remembered than non-emotional events, most likely due to increased levels of arousal. However, the specific valence of an event or stimulus can sometimes have differential effects on our memory. This is certainly the case when comparing the effects of valence on autobiographical memory for emotional events versus emotional memories formed within the laboratory. Whereas laboratory-based research frequently finds that negative emotion has a mnemonic advantage, findings from autobiographical memory research suggest that positive emotion enhances memory (but see evidence from collective memory studies: (Choi, Kensinger, & Rajaram, 2017; Holland & Kensinger, 2012; Kensinger & Schacter, 2006b). On top of this, the differential effects of valence on memory are also known to change with age, with older adults frequently exhibiting a preference in memory for positive over negative information; contrary to the pattern frequently seen in younger adults. While these age-related differences have been explained by the prominent Socio-Emotional Selectivity Theory (SST), there are number of inconsistent findings throughout the literature that cast doubt upon whether the SST is sufficient to explain such age-related differences across all aspects of emotional processing. As such, the current thesis aims to expand on previous literature investigating the effects of emotion, memory and aging in order to explicate some of the current findings and deepen our understanding.

In the first empirical chapter (Chapter 3) this thesis will firstly examine the effects of valence and chronological age on autobiographical memory to determine whether valence has differential effects on long-term subjective and objective measures of autobiographical memory and whether this differs as a function of age. Since many previous flashbulb memory studies concentrate on negative events, it is unclear what effect positive versus negative valence has on long-term flashbulb memories. Secondly, while there is some tentative evidence to suggest that there are age-related impairments associated with flashbulb memories, it could be specific to negative events as positive events are examined less frequently. In other words, it is not currently clear whether the positivity effect extends to flashbulb memories. Therefore, the first aim of this thesis is to understand the effects of valence and aging on long-term autobiographical memories to understand how they compare to laboratory-based findings.

The second aim of this thesis is to test the key predictions of the SST in relation to emotional memory and emotional well-being in order to evaluate the extent to which the theory can explain age-related differences across different domains. As such, the second empirical chapter (Chapter 4) will examine the age-related differences in emotional memory in a more controlled laboratory setting using a combination of behavioural and functional MRI methods. It will test the predictions of the cognitive control extension of the SST and the aging brain model by examining the age-related differences in neural responses to positive, negative and neutral stimuli and in subsequent memory performance. This study will concentrate on areas of the brain that are considered to be important in emotional processing such as the amygdala, the vmPFC and the pregenual ACC which are both associated with emotion regulation (Ochsner et al., 2002; Phelps et al., 2004; Vuilleumier et al., 2001). If the aging brain model is correct, then we would expect to see an overall reduction in amygdala activity within our older adults but not necessarily a difference in prefrontal activity. Conversely, if the cognitive control model is correct, then we would expect to see a reduction in amygdala activity and an increase in prefrontal activation that may indicate increased emotion regulation efforts. Importantly however, as previously mentioned, one prediction of the cognitive control extension of the SST is that the positivity effect is the result of controlled emotional processing. Although there is some research to support this, few studies have examined the temporal changes in neural activation during emotional processing between younger and older adults. If older adults are engaging in cognitive control and implementing emotion regulation strategies that enhance positive affect and dampen negative affect, then it may take time to see their efforts reduce the activity of the amygdala when presented with negative stimuli. As such, the fourth chapter in this thesis attempts to explore this prediction more closely by examining the temporal changes in neural activation that may underlie the positivity effect frequently seen in older adults.

Finally, the third empirical study of this thesis (Chapter 5) will further test the predictions of the SST but this time, will consider the theory across different aspects of emotional processing. Previously, the theory has been used to explain the age-related differences seen in emotional memory, neural responses to emotional stimuli as well as emotional well-being in daily life. However, these three separate areas of emotional processing are often examined in isolation and more recent research investigating the core element of the SST relating to future time perspective, has found opposite patterns to what the SST predicts in terms of emotional well-being. Rather than a more limited future time being associated with better emotional well-being, recent evidence suggests that a limited future time perspective is actually associated with poorer emotional well-being. Therefore, it is currently unclear whether the SST can account for the age-related differences seen in the laboratory as well as in emotional well-being. Therefore, the fifth chapter of this thesis aims to bridge this gap and concurrently investigate the role of future time perspective on emotional processing across behavioural and neural measures to validate the predictions of the SST.

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3. Chapter 3: Memory of the UK’s 2016 EU Referendum: The effects of valence on the long-term measures of a public event.

Chapter 3: Memory of the UK's 2016 EU Referendum: The effects of valence on the long-term measures of a public event.

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3.1 Abstract

Emotional public events, relative to non-emotional ones, are typically remembered more accurately, more vividly and with more confidence. However, the majority of previous studies investigating this have focused on negative public events and less is known about positive ones. Additionally, older adults, compared to younger adults, frequently demonstrate a memorial advantage for positive over negative information but few studies have specifically examined age-related differences in memories for emotional public events. The current study therefore examines whether positive and negative public events are remembered in a similar manner across younger and older adults by assessing individuals' memory for the time when they learned the results of the UK's 2016 Referendum on its European Union (EU) membership. Participants included U.K. participants who voted to '*leave'* the EU in the referendum and found the event highly positive, U.K. participants who voted to '*remain'* in the EU and found the event highly negative, and U.S. participants who did not vote and found the event neutral. Data from a total of 851 participants were assessed at four time points over the course of 16 months. Growth curve modelling showed that differences in memory between participants in the Remain group (who reported the highest levels of negative emotion) and those in the Leave group (who reported the highest levels of positive emotion) emerged over time. Specifically, Remain participants maintained higher levels of memory consistency than Leave participants, while Leave participants maintained higher levels of memory confidence than Remain participants. These results indicate that positive and negative public events are remembered differently, such that negative valence enhances memory accuracy, while positive valence results in overconfidence. However, no age-related effects on memory consistency, confidence or vividness were found.

3.2 Introduction

Emotional items and events are typically remembered better than non-emotional items and events (for reviews see LaBar & Cabeza, 2006; Talmi, 2013) and are often preserved in memory for longer, sometimes spanning several years (Dolcos, Labar, & Cabeza, 2005; Levine & Edelstein, 2009). In lab-based settings, this emotion advantage is evident across a range of different stimuli; including words (Dewhurst & Parry, 2000; LaBar & Phelps, 1998) pictures (Dolcos & Cabeza, 2002; Dolcos, LaBar, & Cabeza, 2004; Nashiro, Sakaki, & Mather, 2012; Ochsner, 2000; Sakaki, Raw, Findlay, & Thottam, 2019) and film clips (Cahill et al., 1996). Emotional stimuli are also often remembered more vividly and with more confidence than neutral stimuli (Cooper, Kensinger, & Ritchey, 2019; Sharot, Delgado, & Phelps, 2004; Sharot, Verfaelli, & Yonelinas, 2007; Todd, Talmi, Schmitz, Susskind, & Anderson, 2012).

Such emotion-induced memory enhancement also extends to real-life autobiographical memories (Talarico, Labar, & Rubin, 2004). One extreme example of such memories are flashbulb memories that are typically formed following a surprising and highly emotional public event, such as the 9/11 terrorist attack (Curci & Luminet, 2006; Hirst et al., 2009; Kvavilashvili, Mirani, Schlagman, Foley, & Kornbrot, 2009) or the deaths of well-known figures (R. Brown & Kulik, 1977; Day & Ross, 2014; Hornstein, Brown, & Mulligan, 2003). Despite the wealth of research on emotion and memory, however, it has been not clearly understood how similarly positive and negative public events are remembered over time. In the current paper, we investigated whether a public event that is interpreted as either positive or negative is similarly remembered over time by assessing individuals' memory for the United Kingdom (UK)'s 2016 Referendum on their European Union (EU) membership.

Previous studies on emotion and memory often focused on the effects of emotional arousal and suggest that highly arousing emotional stimuli are remembered better than neutral stimuli irrespective of emotional valence (LaBar & Cabeza, 2006; Mather & Sutherland, 2009; Schümann, Bayer, Talmi, & Sommer, 2018; Talmi, 2013). However, there is also an increasing recognition that positive and negative valence can influence our memory in different ways (for reviews see Bowen, Kark, & Kensinger, 2018; Kensinger, 2009b). For example, negative faces and scenes were recalled better than positive faces and scenes even when they were matched for arousal (Keightley, Chiew, Anderson, & Grady, 2011). Negatively valenced items are also recalled more precisely (Spachtholz, Kuhbandner, & Pekrun, 2014; Xie & Zhang, 2017) and with a greater sense of vividness than neutral and positive stimuli (Dewhurst & Parry, 2000; Ochsner, 2000; Xie & Zhang, 2016). Recent research has also shown that individuals' abilities to learn associations between pairs are impaired by negative emotion but facilitated by positive emotion (Madan, Caplan, Lau, & Fujiwara, 2012; Madan, Scott, & Kensinger, 2019).

These findings are consistent with several theoretical frameworks, such as the affect-as-information framework (Storbeck & Clore, 2005) and the NEVER (Negative Emotional Valence Enhances Recapitulation) Forget model (Bowen et al., 2018). According to the affect-as-information theory, positive emotion is thought to broaden our scope of attention (Fredrickson & Branigan, 2005) and encourages reliance on general knowledge and scripts (Storbeck & Clore, 2005). Consequently, positive emotion helps us concentrate more on the global characteristics of the event, meaning we are more likely to remember the overall theme or gist (Kensinger, 2009a; Levine & Edelstein, 2009). Conversely, when we experience negative emotion, we adopt bottom-up processing (Clore et al., 2001) and engage in more sensory processes (Mickley & Kensinger, 2008) which enables us to attend to the specific/sensory details of the event. The mental representations of these sensory details are enhanced and are then more likely to be recapitulated at the time of retrieval. This could in turn increase the subjective feelings of vividness in an individual's memory and improve the mnemonic preciseness in the perceptual details associated with negative, rather than positive, memories (Bowen et al., 2018; Bowen & Kensinger, 2017).

However, it is not clearly understood whether and how these laboratory findings extend to memories for real-life events. In fact, positive autobiographical experiences are frequently rated as richer (Ford, Addis, & Giovanello, 2012) and are recalled more frequently (Bohn & Berntsen, 2007; D'Argembeau, Comblain, & Van der Linden, 2003; Walker, Skowronski, & Thompson, 2003) and with greater sensorial detail compared to negative ones (Destun & Kuiper, 1999; Schaefer & Philippot, 2005). These findings are contrary to the findings of lab-based research and suggest the idea that positive emotion may offer a mnemonic advantage over negative emotion. One possible explanation about these differences is that lab-based studies significantly differ in their methodological approaches to autobiographical memory studies. Notably, autobiographical memory studies often focus on what participants remember using a single memory assessment, without having an objective measure about what actually happened. This makes it difficult to understand how positive and negative valence affects the accuracy or consistency of autobiographical memories.

To address this issue, other studies obtained a baseline measure about what has happened to participants (Bohannon, 1988; Hirst et al., 2009; Kraha, Talarico, & Boals, 2014; Kvavilashvili, Mirani, Schlagman, Foley, et al., 2009; Talarico & Moore, 2012). One notable example is research on flashbulb memories. Flashbulb memories are memories about the personal circumstances in which one first learns about a surprising and emotional public event (M. A. Conway et al., 1994; Hirst, Yamashiro, & Coman, 2018), such as the deaths of public figures (Day & Ross, 2014; Demiray & Freund, 2015; Tinti, Schmidt, Testa, & Levine, 2014), political events (e.g., the fall of the Berlin Wall; Bohn & Berntsen, 2007), the resignations of Prime Ministers (M. A. Conway et al., 1994; Stone, Luminet, & Takahashi, 2015), the Fukushima nuclear disaster (Talarico, Bohn, & Wessel, 2019), the inauguration of

President Obama (Koppel, Brown, Stone, Coman, & Hirst, 2013) and sporting events (Breslin & Safer, 2011; Kopietz & Echterhoff, 2014; Merck, Yamashiro, & Hirst, 2020; Talarico & Moore, 2012; Tinti et al., 2014). In research on flashbulb memories, researchers typically assess how participants learnt of an emotional public event shortly after it occurred, followed by a subsequent assessment about the same memory a few months or years later. This method allows researchers to estimate the accuracy of participants' memories based on how consistent their memories are across the multiple assessments (i.e., if their descriptions substantially change between the first vs. subsequent assessments, their memories are less likely to be accurate).

Using such methods, previous research has found that while flashbulb memories are susceptible to distortion (Schmolck, Buffalo, & Squire, 2000; Talarico & Rubin, 2003), they are more accurate than memories for ordinary events (Christianson, 1989; M. A. Conway et al., 1994; Curci & Luminet, 2006; Hornstein et al., 2003). Flashbulb memories are also associated with high confidence (Hirst et al., 2009; Talarico & Rubin, 2007) and high vividness even after a long passage of time (Hirst et al., 2015). These preserved phenomenological features of flashbulb memories are revealed to at least partly depend on emotional responses, such as surprise (R. Brown & Kulik, 1977; Páez et al., 2018), and emotional intensity, suggesting that emotion has beneficial effects on memory even outside of laboratory settings.

While initial research on flashbulb memories are primarily about negative events, more recent research has suggested that individuals can form flashbulb memories even for positive public events (Berntsen & Thomsen, 2005; Kopietz & Echterhoff, 2014; Koppel et al., 2013; Kraha et al., 2014). For example, in one study, researchers assessed memories of the fall of Berlin's wall among German citizens who perceived the event as highly positive, those who perceived it as neutral, and those who perceived it as highly negative (Bohn &

Berntsen, 2007). The results indicated that those who perceived the event as positive experienced a stronger sense of reliving the event during retrieval than those who perceived the event as negative. In another study, older adults were asked to report their memories of their personal circumstances for two events related to their experience of World War II in Denmark: 1) the German occupation of Denmark in 1940 and 2) Denmark's liberation in 1945 (Berntsen & Thomsen, 2005). Memories for the invasion were remembered less clearly than memories for the liberation, suggesting that positive emotion may facilitate the formation of flashbulb memories ─ even more than negative emotion.

To explain these findings, Berntsen proposed the social identity theory of flashbulb memories (Berntsen, 2009). The theory is based on the notion our self-concept includes social identity which concerns our identifications with the social groups that we perceive ourselves as a member of (Tajfel, 1982). Berntsen expanded this theory and posits that individuals form flashbulb memories following a public event when the event is perceived as relevant to a social group to which they belong. When an event is perceived to strongly affect the day-to-day activities of members of a particular social group, it is more likely to attract interest given its perceived importance (Talarico et al., 2019). Consequently, it can lead to stronger emotional reactions (positive or negative), increased rehearsal, and result in frequent communications within the community, such as television/radio programs of the event or conversations about the event with other members in the group (e.g. Day & Ross, 2014), all of which can help the long-term maintenance of these memories. In addition, since groups are striving to maintain a positive self-image, personal circumstances when hearing positive events can be maintained better than personal circumstances when hearing negative public events.

In summary, the social identity theory and laboratory studies suggest different predictions about how valence can affect our memories in life. As discussed above, previous laboratory studies suggest that negative emotion can lead to more accurate and more vivid memories than positive emotion (e.g. Bowen et al., 2018). In contrast, research on autobiographical memory and the social identity theory suggests that positive emotion can have stronger effects on our memory than negative emotion.

Despite such theoretical predictions, there are still relatively few studies that compare memories after a positive versus a negative public event. In addition, those that do make the comparison still provide mixed evidence for the effects of valence. For example some studies have found that vividness (Berntsen & Thomsen, 2005; Breslin & Safer, 2011; Kensinger & Schacter, 2006), confidence (Bohn & Berntsen, 2007; Liu, Ying, & Luo, 2012; Talarico & Moore, 2012) and memory consistency (Liu et al., 2012; Talarico & Moore, 2012) are similar for both positive and negative events. Meanwhile, there is also evidence that positive and negative emotions are differently associated with these measures. For example, some researchers have found an association between positive emotion and higher levels of confidence (Chiew, Harris, & Adcock, 2021; Kensinger & Schacter, 2006; Kraha & Boals, 2014), accuracy and/or clarity (Bohn & Berntsen, 2007; Breslin & Safer, 2011; Koppel et al., 2013; Levine & Bluck, 2004) and vividness (Liu et al., 2012; Talarico & Moore, 2012), offering support for Berntsen's social identity theory. Meanwhile others have found that positive emotion can actually lead to greater levels of inaccuracy (Bohn & Berntsen, 2007; Demiray & Freund, 2015; Kensinger & Schacter, 2006; Levine & Bluck, 2004), which is more consistent with the results found in laboratory-based studies.

Furthermore, across these studies, there are two issues which make the interpretation and comparability between them difficult. Firstly, the events themselves are often two separate events (one representative of each valence) that are arguably different in their qualities (Koppel et al., 2013; Kraha et al., 2014). For example, positive events are often personal ones such as being accepted to college, while the negative events are frequently public events such as natural disasters or tragedies, like the 9/11 terror attack (Kraha & Boals, 2014; Kraha et al., 2014; Liu et al., 2012). Therefore, it is difficult to know whether the differences in memory measures are due to the valence of the events or due to other confounds (e.g., public events receive more media attention than personal events).

Secondly, previous studies have relied upon one single follow-up assessment which is often obtained at different intervals across studies. However, having a single memory assessment prevents us from being able to understand how emotional autobiographical memories may manifest over time. Likewise, the duration between the event and the initial assessment may also vary for positive and negative events. For example, previous evidence suggests that short-term assessments yield similar levels of consistency and confidence for positive and negative events (Talarico & Moore, 2012) while longer intervals lead to better memory accuracy but lower confidence for negative events (Kensinger & Schacter, 2006). Therefore, these conflicting findings may simply be due to the differences in the duration between the event and the assessment of memory as opposed to the direct effects of valence.

Meanwhile, returning back to the different predictions about how valence can affect our memories in real-life, there is an additional factor which is underexplored in the flashbulb memory literature; the effects of chronological age. In the wider emotional memory literature, older adults, like younger adults, also benefit from emotionally arousing stimuli (Murphy & Isaacowitz, 2008) however, they often demonstrate a different pattern in terms of valence. More specifically, older adults frequently exhibit a preference for positive over negative information in attention and memory compared to younger adults who often show the opposite pattern (for a review see Reed, Chan, & Mikels, 2014). This phenomena is more widely known as the *positivity effect* which is thought to be a consequence of older adults focusing more on emotion regulation strategies than younger adults which enables them to maximize feelings of positive affect (Mather & Carstensen, 2005). Several studies have found age by valence interactions in memory for emotional stimuli whereby older adults remember more positive information or less negative information relative to younger adults (Charles, Mather, & Carstensen, 2003; Mather & Knight, 2005; Tomaszczyk, Fernandes, & MacLeod, 2008). For example, Carstensen and Mikels (2005) found that older adults, compared to younger adults, had better memory for positive relative to negative emotional stimuli. Importantly, the positivity effect is also thought to extend to autobiographical memories too (Kennedy, Mather, & Carstensen, 2004; Schlagman, Schulz, & Kvavilashvili, 2006; Tomaszczyk & Fernandes, 2012) however, few studies have examined the positivity effect in the context of flashbulb memories specifically (but see Breslin & Safer, 2013).

Instead, many studies have simply investigated age-related differences in flashbulb memory formation and maintenance and the findings provide mixed support for age-related differences. On the one hand, some studies find that older adults show poorer memory compared to their younger counterparts (e.g. Kensinger, Krendl, & Corkin, 2006; Tekcan & Peynircioğlu, 2002) which dovetails nicely with the findings from laboratory-based studies that often find age-related impairments in memory recall (Danckert & Craik, 2013) and recognition (Fraundorf, Hourihan, Peters, & Benjamin, 2019). At the same time, other researchers have failed to find age-related effects in flashbulb memories (e.g. A. R. A. Conway, Skitka, Hemmerich, & Kershaw, 2009; Kvavilashvili, Mirani, Schlagman, Erskine, & Kornbrot, 2010; Wright, Gaskell, & O'Muircheartaigh, 1998) and instead have found that older adults are just as likely as younger adults to recall where they were when they learned about the news/event and how they found out (Davidson, Cook, & Glisky, 2006; Davidson & Glisky, 2002).

More recently, the findings of a meta-analysis which aimed to synthesize the findings of such studies examining age-related effects on flashbulb memory formation (Kopp, Sockol, & Multhaup, 2020) found a small-to-moderate age-related impairment in flashbulb memory scores. More specifically, they found that older adults were less likely than younger adults to meet criteria for having a flashbulb memory suggesting that older adults perhaps did not benefit as much from the emotional enhancement that is typically associated with flashbulb events. In addition, they also found that compared to younger adults, older adults were less consistent in their flashbulb memories over time. However, a notable limitation of the meta-analysis is that many of the studies included, concentrated specifically on negative events such as the 9/11 terrorist attack (Davidson et al., 2006; Denver, Lane, & Cherry, 2010; Gerdy, Multhaup, & Ivey, 2007; Kvavilashvili, Mirani, Schlagman, Wellsted, & Kornbrot, 2009) and the deaths of notable figures such as President John F. Kennedy (Yarmey & Bull, 1978), Mother Teresa (Davidson et al., 2006) and Princess Diana (Kvavilashvili, Mirani, Schlagman, Wellsted, et al., 2009). As such, these age-related deficits seen in flashbulb memory studies could be specific to negative events and could actually be evidence of the positivity effect in the form of a reduced negativity bias compared to younger adults (e.g. Grühn, Scheibe, & Baltes, 2007; Mantantzis, Schlaghecken, & Maylor, 2020; Mather & Knight, 2005). However, since many of these studies also suffer from the same limitations as previously mentioned i.e. they do not include or compare positive versus negative events, it is difficult to know whether the positivity effect is in fact evident in flashbulb memories.

That being said, to our knowledge, there is one study that has examined age-related differences for both a positive and negative public event (Breslin & Safer, 2013). In this study, younger and older baseball fans, whose ages ranged between younger than 25 and older than 65, were asked about their memory for two noteworthy baseball fixtures between two rival teams: the Red Sox and the Yankees. Their results indicated no age by valence interactions in terms of memory accuracy or memory vividness. In other words, they failed to find support for the positivity effect. However it is worth noting that the objective memory assessment in this particular study concerned factual questions surrounding the sports events such as what the final score was and where the games were held. As such, these factual questions were different to the typical source memory questions such as where they were, what time it was, who they were with, how they found out etc. Therefore, it is unclear whether these findings are specific to the factual details of an event as opposed to the source memory questions that are often probed in a flashbulb memory study.

3.2.1 Current Research

The current research aims to address the aforementioned issues by assessing younger and older participants' memory for a single event over four separate surveys in order to reveal the effects of valence on emotional event memories. Moreover, we aimed to determine whether or not there are any age by valence interactions in memories for emotional events that replicate the positivity effect seen in laboratory-based research and other autobiographical memory research. Thirdly, drawing on the large body of research on flashbulb memories, we also aimed to examine how memories for positive and negative public events similarly vs. differently rely upon factors that have been implicated in the formation and the maintenance of flashbulb memories beyond emotional reactions, including levels of rehearsal and personal importance (M. A. Conway et al., 1994; Finkenauer et al., 1998; Talarico & Rubin, 2017).

To achieve these goals, we assessed memory for the same event – the UK's 2016 EU Referendum in which the public voted for the U.K. to leave the European Union (EU) membership, in (a) U.K. participants who voted to leave the EU and found the event highly positive (i.e., Leave) and (b) U.K. participants who voted to remain in the EU and found the event highly negative (i.e., Remain). The referendum result indicated the UK's future intention to end the political and economic partnership with the EU that had been maintained since 1975. Thus, it had the potential to affect lives of many individuals who lived in the

U.K. in a range of domains: legislation, the freedom of movement, the UK's trade with other EU countries and so on. Leading up to the official vote, both online- and telephone-polls yielded neck and neck results for both *Leave* and *Remain* parties, signalling a high level of uncertainty in the overall outcome (Barnes, 2016). The marginal 'Leave' win with 51.9% of the votes (The Electoral Commission, 2016) was met with high levels of surprise both amongst the U.K. public and World-Leaders. Therefore, this political event provided us with an ideal opportunity to investigate peoples' memories for a highly surprising and important event that yielded both a positive and negative outcome depending on peoples' voting choice (i.e. Leave vs. Remain). As is the case in other studies of public events (M. A. Conway et al., 1994; Curci, Luminet, Finkenauer, & Gisle, 2001; Kvavilashvili, Mirani, Schlagman, & Kornbrot, 2003; Luminet et al., 2004; Tinti, Schmidt, Sotgiu, Testa, & Curci, 2009), a control group from outside the region/country where the event occurred was also included. In this specific event, U.S. participants did not vote on the issue and were presumed to have more emotionally neutral feelings towards the event; as such, we recruited U.S. residents who did not vote in the referendum as the control group.

Using such a design, we examined the effects of valence on consistency, confidence and vividness for memory for the same event over time. In four separate surveys, at one week and then, three, nine and 16 months after the EU Referendum results, participants answered a number of questions relating to their memory for when they learnt about the EU Referendum results. We focused on the consistency of canonical features of the memories (R. Brown & Kulik, 1977), including where they were, what time it was, who they were with, how they found out (source of information), what they were doing beforehand, and what they did afterwards. We also assessed subjective memory vividness, subjective memory confidence, positive emotion, negative emotion, and other factors that have been implicated in the formation of flashbulb memories, such as surprise, rehearsal, and personal importance.

U.K. participants were able to vote in the referendum; an event that was arguably highly relevant to their social group status as U.K. participants. They were thus more likely to be invested in the outcome and be directly impacted by the results than U.S. participants were. Therefore, we expected that compared to their U.S. counterparts, the two U.K. voting groups would be more likely to form memories that have features similar to flashbulb memories (i.e., memories that were more confidently held, more consistent and more vivid) due to their higher levels of long-term personal importance, emotional intensity, surprise and rehearsal. We also expected Remain participants to report higher ratings of negative emotion than Leave participants and U.S. participants because the results of the referendum were not congruent with their voting choice. In contrast, we expected that Leave participants expressed higher ratings of positive emotion than Remain participants and U.S. participants. Given that the previous literature provides mixed results on whether a particular valence is associated with more consistent, more vivid and/or more confidently held memories, we did not have a specific directional hypothesis but examined a) whether Remain and Leave participants demonstrated different levels of memory consistency, vividness and confidence; and b) whether any differences between the two groups changed across time. In terms of age however, we expected that older adults would demonstrate the positivity effect in the form of increased memory for positive events or reduced memory for negative events relative to younger adults. We also examined whether the effects of voting choice on our memory measures were mediated by any of the factors identified in the literature such as positive emotion, negative emotion, surprise, rehearsal and personal importance.

3.3 Methods

3.3.1 Participants

Participants were aged between 18 and 87 and resided in either the U.K. or the U.S. They were recruited through Prolific (https://www.prolific.co/), other websites such as http://psych.hanover.edu/research/exponnet.html, personal communications, the Undergraduate Research Panel at the University of Reading in the U.K. and the Older Adult Research Panel at the University of Reading. Participants recruited from Prolific were pre-screened so that we could target those (i) with a U.K. or U.S. nationality, (ii) who resided in the U.K. or U.S., (iii) who were born in the U.K. or U.S., (iv) who voted in the EU referendum (for U.K. participants)[1] and (v) with a study approval rating of 90% and above which has previously been associated with higher quality data (Peer, Vosgerau, & Acquisti, 2014). Participants recruited from Prolific were paid £1 after completing each survey and students from the Undergraduate Research Panel received course credit after completing each survey. The remaining participants received an Amazon money voucher (£1 per survey), or a check (£1 per survey) after completing all follow up surveys. Participants signed an electronic version of the consent form that was given a favourable opinion by the University Research Ethics Committee.

In order to model the change in memory consistency over time, it was important for us to have data from participants who had completed the initial survey and at least two other follow-up surveys. Considering an expected return rate between 55 and 70% for each survey as is seen in previous longitudinal flashbulb memory studies (Holland & Kensinger, 2012; Levine & Bluck, 2004), we aimed to recruit at least 150 participants (per group) in the first survey to achieve the statistical power of .80 to detect the valence effects observed in Kensinger and Schacter (2006) in the final sample. At the end of each survey, participants were asked if they would be happy to be contacted again for a follow-up survey and if so, were asked to provide an email address. For ethical reasons, only those that stated ‘yes’ to the follow-up invitation were invited back. For the third and fourth survey, we invited all

[1] This was implemented from Survey 2 onward. While collecting data for Survey 2, we also specifically recruited participants who voted to *leave* the EU in Prolific in order to recruit a similar number of Leave and Remain participants.

participants who had previously indicated their willingness to be contacted again, even if they had missed a survey in between. For each follow-up study, we also recruited additional participants who had not completed the previous survey to increase our statistical power.

Prior to data analysis, we removed data from participants due to the following exclusion criteria. First, we excluded data from those (i) who did not complete the consent form process correctly (*n* = 3), (ii) who provided answers that were not genuine and did not answer the questions correctly (*n* = 1; e.g., entering lengthy paragraphs relating to a completely different topic and (iii) those who could not be tracked due to inaccuracies in their unique identifying code/ Prolific ID from each individual survey wave (*n* = 16). Second, we checked for duplicated answers and found that 36 participants completed one of the surveys more than once; for these participants, we removed their second responses and used their first responses in our analyses. We next identified participants who could not be clearly assigned to a group (e.g., non-U.K. nationals who resided in the U.K. but were not eligible to vote; U.K. nationals who resided in the U.S.); data from these participants (*n* = 212) were also not included in our analysis. In addition, since our longitudinal analysis required participants to have more than one survey observation, we could not include data from participants who had completed one survey only (*n* = 899). To ensure reliability of data and to address possible occasions of character misrepresentation (Chandler & Paolacci, 2017; Shapiro, Chandler, & Mueller, 2013) in the remaining sample, we also excluded data from participants (i) who did not provide consistent answers to questions on demographic and voting questions (e.g. gender, voting choice, voting eligibility and age) across different surveys and (ii) those who never had a U.K. or U.S. IP address across (Keith, Tay, & Harms, 2017) any of the surveys they participated in (*n* = 29).

Participants included in the final analysis for memory vividness and confidence included a total of 851 individuals comprised of 267 Leave (149 females; age range: 18-82;

*M*age = 42.94, SD = 14.04; Survey 1: 153, Survey 2: 214, Survey 3: 212, Survey 4: 174), 275 Remain (178 females; age range: 18-87; *M*age = 40.10, SD = 16.94; Survey 1: 190, Survey 2: 226, Survey 3: 222, Survey 4: 176) and 309 U.S. participants (149 females; age range: 18-77; *M*age = 36.88, SD = 13.65; Survey 1: 217, Survey 2: 238, Survey 3: 228, Survey 4: 163; see Table 3.1). As memory consistency scores could only be generated if the participant had taken part in the initial survey (see 3.3.3 Coding of Autobiographical Memories), analyses on this measure were performed on data from a sub-set of participants who completed the first survey: 153 Leave (90 females; age range: 18-83; *M*age = 43.07, SD = 15.21; Survey 1: 153, Survey 2: 140, Survey 3: 98, Survey 4: 80), 190 Remain (120 females; age range: 18-87; *M*age = 41.94, SD = 17.69; Survey 1: 195, Survey 2: 172, Survey 3: 139, Survey 4: 112) and 217 U.S. participants (91 females; age range: 18-75; *M*age = 37.41, SD = 13.79; Survey 1: 217, Survey 2: 177, Survey 3: 144, Survey 4: 94)[2].

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[2] To compare those who completed Survey 1 only vs. those who completed Survey 1 and later surveys, a series of 2 (returning status: Survey 1 only vs. returning participants) x 3 (voting group: Remain, Leave vs. U.S.) ANOVAs were conducted as well as a chi-square test of independence for gender (males vs. females) by returning status (Survey 1 only vs. returning participants). These analyses showed that there were no differences in those who dropped out vs. those who remained on gender, $\chi 2$ (1) = 2.74, p =.09, their initial levels of memory vividness, F (1, 902) = 1.98, p = .16, η^2 = .002, surprise, F (1, 902) = 0.07, p = .79, η^2 = .001, personal importance, F (1, 902) = 1.03, p = .47, η^2 = .001, or negative emotion, F (1, 902) = 1.25, p = .27, η^2 = .001. However, we found significant main effects of returning status for age, F (1, 902) = 14.46, p < .00, η^2 = 0.02, and a significant interaction for level of education, F (2, 894) = 6.51, p < .01, η^2 = 0.01. Those who returned to the survey were older (*M* = 38.77, *SD* = 15.45) than adults who dropped out (*M* = 35.45, *SD* = 13.73) and among Remain participants, those who dropped out had lower levels of education (*M* = 4.04, *SD* = 0.93) than those who returned (*M* = 4.42, *SD* = 1.02; p < .001). In addition, we found a main effect of returning status for initial levels of rehearsal, F (1, 894) = 6.24, p = .015, η^2 = 0.01, indicating that returning participants reported higher levels of rehearsal (*M* = 3.94, *SD* = 1.03) compared to those who did not return (*M* = 3.74, *SD* = 1.12). The same was found for initial levels of positive emotion, F (1, 901) = 4.01, p = .045, η^2 = 0.004. When examining the number of surveys taken, we found a main effect of group, F (1,558) = 9.58, p < .001, η^2 = 0.02. Post-hoc comparisons using Bonferroni's

3.3.2 Procedure

The surveys were administered using SurveyGizmo[3] (https://www.surveygizmo.com). Figure 3.1 represents the timing of each survey. Survey 1 started on July 01, 2016 - one week after the EU Referendum results were announced on June 24, 2016, and continued for a period of ten days until the 11 July, 2016. For the second and third surveys (Surveys 2 and 3), we recruited participants for three weeks and for the fourth survey (Survey 4), the duration of recruitment was increased to 3 weeks and 5 days to maximize participant retention. The recruitment dates and duration for each follow-up survey were as follows: Survey 2 was between October 14, 2016 and November 11, 2016, Survey 3 was between April 5, 2017 and April 26, 2017 and Session 4 was between October 13, 2017 and November 8, 2017.

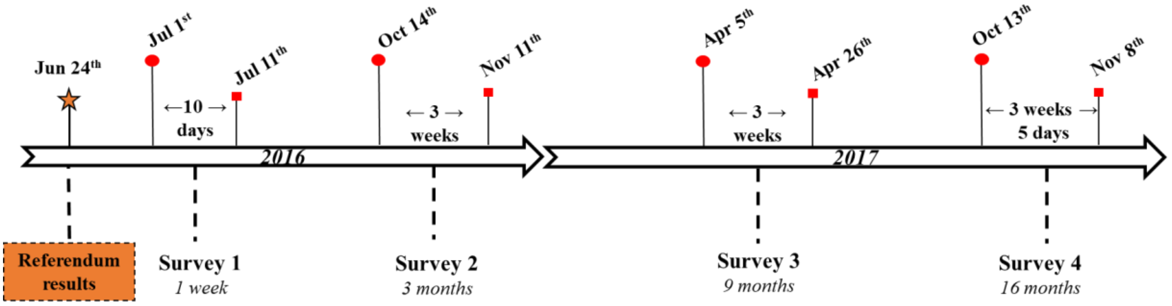

Figure 3.1. Timeline of survey administration including start and end dates and duration for each survey.

3.3.2.1 Surveys

Each survey began with an electronic information sheet, detailing the purpose and aim of the study along with an electronic consent form. Each returning participant was also sent a unique identifying code that they generated in the previous survey, allowing us to track them

correction found that Remain participants, on average, participated in a greater number of surveys than U.S. participants, $p < .001$.

[3] Now called Alchemer (https://www.alchemer.com/).

over time. Participants were told that the study concerned their memories for the U.K.'s 2016 EU referendum. The main content in each survey was similar across the four surveys (see Appendices 3.7, Appendix 1). In the current study, we focused on the following questions: a) participants' voting choice, b) their memories of learning the outcome of the EU referendum, and c) potential predictors of the formation and maintenance of flashbulb memories implicated in the literature (see Appendices 3.7, Appendix 1; Table A1 for a summary of the questions that are relevant to the results presented in this chapter and Chapter 7, Appendix A for a comprehensive list of questions administered in the study).

Voting choice. Participants were asked to indicate their voting eligibility ("*Were you eligible to vote in the 2016 UK's EU referendum?*"; Question 9 in Appendix 1). Those who indicated that they were eligible were further asked to indicate their voting choice (*"How did you vote?"*; Question 10) with three options: (a) "*to leave the EU"*, (b) "*to remain in the EU"* or (c) "*I was eligible but did not vote*".

Memory properties. We administered six questions to establish consistency of their memories (Questions 2-7 in Appendix 1) by asking for their circumstances when they found out the results of the referendum. The questions were taken from previous studies on flashbulb memories (e.g. R. Brown & Kulik, 1977; Hirst et al., 2009) and covered the following aspects: (i) the time: *"What time was it when you found out the results?";* (ii) the source of information: *"How did you learn the outcome?"*; (iii) the location: *"Where were you when you found out the results?"*; (iv) other people: *"Who else was there when you found out?"*; (v) activities beforehand: "*What were you doing beforehand?*"; and (vi) activities afterwards: "*What did you do immediately after finding out the results?*" For the question about the source of information, participants were asked to select if they had learned the outcome through a) the television, b) the internet, c) friends and family, d) a newspaper, e) the radio or f) other. For the remaining questions, participants were asked to describe their circumstances in one sentence. They were also told that their responses to these questions should be specific. We also assessed subjective vividness of their memory (*"How vividly do you remember the time you became aware of the referendum outcome?"*; Question 1*)* with a 7-point Likert scale (1: "not very" – 7: "extremely"). In Survey 2 and subsequent surveys, we also measured their memory confidence (*"How confident are you in your overall recollection of when you found out the referendum results?"*; Question 8) again with a 7-point Likert scale (1: "not at all" – 7: "extremely").

Table 3.1.

Demographic information for participants included in the analysis.

Demographic items	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**
	(n = 560)	(n = 678)	(n = 662)	(n = 513)
		Remain voters		
n	190	226	222	176
Age range in years	18-86	18-87	18-84	19-85
Age Mean (SD)	39.91 (17.25)	39.91 (17.07)	39.67 (16.58)	41.39 (16.99)
Females	120	145	148	110
Recruit Type (n)				
Volunteer / Student	134	141	126	96
Prolific	30	59	73	58
Older Adult Research Panel	26	26	23	22
Education Level (%)				
School-level qualification (GCSE/A-Level/ College Equivalent)	15%	8%	18%	15%
Undergraduate Degree	44%	9%	44%	44%
Post-graduate Degree	42%	5%	38%	41%
Prefer not to say / Did not answer	0%	1%	0%	0%
Missing	-	77%	-	-
Political Affiliation (%) [1]				
Right-wing	11%	4%	14%	13%
Left-wing	42%	10%	37%	50%
Centre	12%	2%	14%	11%
Other	13%	1%	8%	3%
Prefer not to say / None	22%	6%	27%	23%
Missing	0%	77%	0%	1%
		Leave Voters		

n	153	214	212	174
Age range in years	18-82	18-82	18-82	19-83
Age Mean (SD)	41.24 (14.95)	42.94 (14.28)	43.00 (13.84)	44.36 (13.08)
Females	90	121	116	96
Recruit Type (n)				
Volunteer / Student	16	23	22	14
Prolific	127	178	178	150
Older Adult Research Panel	10	13	12	10
Education Level (%)				
School-level qualification (GCSE/A-Level/ College Equivalent)	46%	16%	48%	45%
Undergraduate Degree	41%	13%	37%	39%
Post-graduate Degree	11%	4%	14%	13%
Prefer not to say / Did not answer	1%	0%	1%	0%
Missing	0%	66%	0%	1%
Political Affiliation (%) [1]				
Right-wing	50%	17%	62%	49%
Left-wing	14%	5%	9%	19%
Centre	2%	1%	0%	1%
Other	2%	0%	4%	3%
Prefer not to say / None	32%	10%	24%	28%
Missing	0%	67%	1%	0%
U.S. Participants				
n	217	238	228	163
Age range in years	18-74	18-75	19-77	19-77
Age Mean (SD)	36.03 (13.69)	36.97 (13.56)	36.56 (13.47)	38.35 (14.00)
Females	91	105	114	81
Recruit Type (n)				
Volunteer / Student	3	6	4	3
Prolific	214	232	224	160
Education Level (%)				
School-level qualification (GCSE/A-Level/ College Equivalent)	41%	9%	35%	37%
Undergraduate Degree	46%	9%	46%	42%
Post-graduate Degree	13%	4%	16%	20%
Prefer not to say / Did not answer	0%	0%	2%	0%
Missing	0%	77%	0%	1%
Political Affiliation (%) [1]				
Right-wing	18%	5%	18%	17%
Left-wing	47%	13%	50%	48%
Centre	2%	1%	1%	2%
Other	13%	1%	9%	7%
Prefer not to say / None	20%	4%	22%	25%

Missing	0%	77%	0%	1%

[1] Right-wing parties included the Conservatives (UK), United Kingdom National Party (U.K.) and Republicans (U.S.A.), the Left-wing parties included Labour (U.K.), Scottish National Party (U.K.) and Democrats (U.S.) and the Centre parties included Liberal Democrats (U.K.).

Potential predictors.

Positive and negative emotion. Participants were presented with five items (*angry*, *sad*, *anxious*, *happy* and *proud*) and asked to indicate how strongly they felt each of these emotions when they thought of the referendum (Questions 11a-11e; all with 7-point Likert scales ranging from 1: "not at all" to 7: "very strongly").

Two separate scores were created: one to reflect negative emotion by averaging the three items on negative emotion (*angry*, *sad* and *anxious;* $\alpha = .89$) and one to reflect positive emotion by averaging the two items on positive emotion (*happy* and *proud;* $r = .91$, $p < .001$; see Appendix 3, Table A2 for their correlations at Survey 1).

Surprise. Participants also indicated how strongly they felt surprise when they thought of the referendum (Question 11f; using the same 7-point Likert scale as the one used for other emotional states). Although surprise is considered to be an emotional reaction, it is often considered to be a separate predictor to emotional intensity (Bohn & Berntsen, 2007; M. A. Conway et al., 1994; Er, 2003; Finkenauer et al., 1998). In addition, surprise is often emotionally neutral (Fontaine, Scherer, Roesch, & Ellsworth, 2007). Therefore, ratings of surprise were used as an independent measure from the other items on emotion.

Personal importance. Levels of personal importance were assessed using a single question (*"How important are the referendum results to you?"*) with a 7-point Likert scale ranging from 1 ("not important") to 7 ("extremely important"; Appendices, 3.7, Table A1, Question 12). The question was based on similar items used in previous studies on memories for public events (Holland & Kensinger, 2012; Kensinger, Krendl, et al., 2006).

Rehearsal. We also assessed levels of rehearsal. In Survey 1, we used four questions (Questions 13-16). Three of them were obtained from previous studies (Bohn & Berntsen, 2007; M. A. Conway et al., 1994; Kensinger & Schacter, 2006) and asked participants to indicate: 1) how much they followed the media coverage of the referendum result in the past week, 2) how much they thought about the referendum since finding out the results, and 3) how much they talked about the referendum with their friends/family and colleagues. We also expected that many participants relied on the internet to gather information (Hirst et al., 2010; Luminet et al., 2004; E. G. Schaefer et al., 2011) and therefore added one more question: how much they spent on the internet reading the latest news about the referendum in the past week. For all questions, participants were asked to indicate the most appropriate option on a scale ranging from 1 ("*rarely or none of the time or less than 1 day"*) to 5 ("*daily"*). In Surveys 2-4, we used similar questions (Questions 17-19) but changed them to assess how much participants had engaged in each activity since the previous survey. We also used a 7-point Likert scales (1: "Very little" – 7: "A great deal") in these follow up assessments.

A current rehearsal score was calculated for Surveys 2, 3 and 4 by averaging the four questions (Questions a-d for 17-19 respectively; α values >.92). We also obtained the average level of rehearsal at Survey 1 by averaging Questions 13-16 (α = .92); since these questions were answered using a different scale (a 5-point scale) than rehearsal-related questions in the rest of the surveys (a 7-point scale), we did not compare levels of rehearsal at Survey 1 versus those at the follow-up surveys.

3.3.3 Coding of Autobiographical Memories

In order to assess memory consistency over time, the participants' responses to the six main questions (Questions 2-7) from each survey were coded using an adapted version of the Hirst et al. (2009) coding scheme (see Appendices 3.7, Appendix 2 for further details of coding and Chapter 7, Appendix B for the full coding hand-book). This allowed us to create a consistency score for each of the six questions by comparing the coding values in Survey 1 with coding values in Surveys 2, 3 and 4 separately, using the Survey 1 coding value as the baseline measure. Unlike other coding schemes that allow for memories to be considered consistent with varying levels of specificity (e.g. Neisser & Harsch, 1992), the one developed by Hirst and colleagues uses a two-point classification scheme in which responses are classified as either *inconsistent* or *consistent*. For example, if the coding values in Surveys 2, 3 and 4 were the same as Survey 1, the response was given a "1" to reflect *consistency*. If the coding values differed to Survey 1, then a "0" was given to reflect *inconsistency.* Our final memory consistency score was the averaged overall consistency of the six questions ranging from 0 to 1. The coding was done by several coders who were blind to the survey time and the group the participant belonged to. For each question, a subset (5%) of the responses was coded by two coders to assess interrater reliability. The percentage agreement between coders was high (>82%); see Appendix 3.7.3.4 for results when we used a coding approach similar to the one used in Neisser and Harsch (1992).

3.3.3.1 Coding of Changes in Memory Content over Time

To determine whether a positive event was associated with a greater tendency to repeat inconsistent memories than a negative event was and to examine how incorrectly remembered memories change over time, we undertook a second round of coding to assess the consistency between inter-survey responses (i.e., comparing Survey 2 with Survey 3 and Survey 4 and comparing Survey 3 with Survey 4). As done in Hirst et al. (2009), this allowed us to examine whether incorrect memories were repeated, corrected or changed in the subsequent survey. For each question, a subset (10%) of the responses was coded by two coders to assess interrater reliability. The percentage agreement between coders was high (>88%).

3.3.4 Data Analysis

Effects of residency and voting choice on memory properties. One of our primary analyses concerned the effects of voting choice (Leave vs Remain) and residency (U.K. vs US) on memory consistency, memory vividness and memory confidence. A series of analyses using structural equation modelling (SEM) were carried out in RStudio (v. 1.3.1093) using the *lavaan* (v. 0.6-7) package (Rosseel, 2012). Specifically, we specified growth curve modelling with SEM (Duncan, Duncan, & Strycker, 2006). This model allowed us to estimate whether voting groups have any short- (initial levels that are reflected by the *intercept*) and long-term effects (the growth over time that are reflected by the *slope*) on our dependent variables. Memory consistency, confidence and vividness were treated as the dependent variables and each was modelled separately. Orthogonal contrast coding was used to create two group variables; the first was used to compare U.S. participants with U.K. participants (Leave participants = -1, Remain participants = -1, and U.S. participants = 2; referred to as *U.K. vs U.S.* in the model) and the second was used to compare Remain with Leave (Remain participants = 1, Leave participants = -1 and U.S. participants = 0; referred to as *Leave vs Remain* in the model). Each model was estimated using maximum likelihood estimations. In addition, a Comparative Fit Measure (CFI), the Robust Tucker-Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA) were used to compare the fit of the model. In order to determine a good statistical fit, we accepted models that had CFI and TLI values >.90 (Kline, 2016) and RMSEA values < .08 (Browne & Cudeck, 1993).

Effects of residency and voting choice on emotional experience and other

potential predictors of memory measures. To examine how residency and voting choice affected positive emotion, negative emotion and other potential predictors implicated in the formation of flashbulb memories, such as surprise, rehearsal, and personal importance, another series of growth curve modelling were carried out in RStudio, again using the *lavaan* package. The dependent variables were participants' ratings of the intensity of negative emotion, positive emotion, surprise, rehearsal, and importance, each of which was modelled separately. As in the previous analysis, orthogonal contrast coding was used to create two group variables; *'U.K. vs U.S.'* and *'Leave vs Remain'.* This analysis allowed us to assess whether the initial ratings of negative emotion, positive emotion, surprise, rehearsal and personal importance differed across residency and voting group; and whether these variables changed over time in a similar manner across the three groups of participants.

Mediation analysis. In order to understand whether levels of the potential predictors (e.g., surprise, personal importance, negative emotion, positive emotion and rehearsal) mediate the effects of residency and voting group on memory consistency, confidence and vividness, we ran three separate mediation analyses. Memory consistency, confidence and vividness were each treated as the dependent variable in these three separate models. Across all three models, the independent variables were residency and voting group and the mediation variables were Survey 1 measures of negative emotion, positive emotion, surprise, personal importance and rehearsal.

3.4 Results

Table 3.1 describes the demographic characteristics of participants included in our analyses. Table 3.2 describes the means and standard deviations for our main variables for each time point. As described in the Appendix 3.7.3.1, our three groups of participants differed on measures of age, gender and education. However, controlling for these variables did not change most of our key results concerning the differences across the two voting groups[4]. Therefore, we report results from analyses without controlling for age, gender and education (see Appendix 3, Tables A3-4 for results when we controlled these additional variables).

The section is divided into four subsections. In the first section, we present results concerning our first hypothesis that Leave participants should experience more positive emotions and Remain participants should experience more negative emotions towards the EU referendum. In the second section, we describe the effects of the three groups on our three memory measures (i.e., consistency, vividness and confidence). In the third section, we describe results concerning whether the three groups differently affect potential predictors of flashbulb memories (surprise, personal importance, and rehearsal). Lastly, we present results from the mediation analyses, where we examined whether any of these predictors as well as our emotion measures mediate the group effects on memory measures.

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[4] There are two exceptions: a) the effects of residency on the slope of memory consistency and b) the initial levels of memory vividness. However, for both of these separate analyses, the results were largely similar irrespective of whether we controlled for the effects of age, gender and education. More specifically, when we did not control for age, gender and education, we found a significant difference in the slope of memory consistency between U.S. and U.K. participants, which was no longer significant when we controlled for age, gender and education. However, subsequent mediation analyses confirmed a significant difference between U.K. vs. U.S. participants in the slope for memory consistency irrespective of whether we controlled the effects of age, gender and education. Likewise, when we did not control for age, gender, and education, we found a significant difference in the initial memory vividness between Leave and Remain participants. This effect was no longer significant after controlling for age, gender and education. Nevertheless, subsequent mediation analyses provided a similar picture irrespective of whether we controlled for age, education and gender. Specifically, the analysis revealed that Remain vs. Leave participants were statistically different in their initial memory vividness due to group differences in importance, positive emotion and rehearsal.

Table 3.2

Consistency, Confidence and Vividness in Flashbulb Memories and Negative Emotion, Personal Importance, Surprise and Rehearsal as a Function of Voting Group and Residency, Across All Surveys

Memory assessments and survey	Remain		Leave		U.S.	
	M (SD)	*n*	*M* (SD)	*n*	*M* (SD)	*n*
Flashbulb Memory Consistency						
3 Months	0.71 (0.19)	174	0.67 (0.19)	142	0.55 (0.21)	182
9 Months	0.68 (0.19)	140	0.63 (0.21)	98	0.56 (0.23)	144
16 Months	0.71 (0.19)	113	0.60 (0.18)	80	0.55 (0.20)	94
Flashbulb Memory Confidence						
3 Months	5.91 (1.04)	226	5.75 (1.30)	214	4.37 (1.65)	238
9 Months	5.59 (1.24)	222	5.62 (1.45)	212	4.34 (1.70)	228
16 Months	5.40 (1.26)	176	5.52 (1.43)	174	3.96 (1.75)	163
Flashbulb Memory Vividness						
0 Months	6.53 (0.83)	190	6.25 (1.14)	153	5.1 (1.73)	217
3 Months	6.21 (1.06)	226	6.01 (1.37)	214	4.13 (1.84)	238
9 Months	6.05 (1.17)	222	5.97 (1.34)	212	4.16 (1.78)	228
16 Months	5.77 (1.38)	176	5.58 (1.70)	174	3.65 (1.70)	163
Negative Emotion						
0 Months	5.31 (1.34)	190	2.36 (1.35)	153	2.66 (1.57)	217
3 Months	5.00 (1.51)	226	2.08 (1.29)	214	2.23 (1.37)	238
9 Months	4.96 (1.55)	222	1.99 (1.17)	212	2.39 (1.52)	228
16 Months	4.89 (1.63)	176	2.24 (1.30)	174	2.18 (1.43)	163
Positive Emotion						
0 Months	1.22 (0.59)	190	4.70 (1.92)	153	2.07 (1.67)	216
3 Months	1.33 (0.72)	226	4.69 (1.97)	214	1.83 (1.47)	238
9 Months	1.29 (0.62)	222	4.97 (1.75)	212	1.95 (1.58)	228
16 Months	1.30 (0.72)	176	4.47 (1.91)	174	1.77 (1.46)	163
Personal Importance						

0 Months	6.41 (0.78)	189	5.83 (1.31)	153	3.81 (1.64)	217
3 Months	6.14 (1.01)	226	5.83 (1.26)	214	3.41 (1.53)	238
9 Months	5.99 (1.15)	222	5.93 (1.22)	212	3.51 (1.62)	228
16 Months	6.06 (1.12)	176	5.80 (1.25)	174	3.29 (1.63)	163
Surprise						
0 Months	3.95 (1.79)	190	4.22 (1.84)	153	3.69 (1.77)	217
3 Months	3.77 (1.82)	226	3.73 (1.89)	214	3.11 (1.87)	238
9 Months	3.53 (1.67)	222	3.83 (1.78)	212	3.14 (1.92)	228
16 Months	3.65 (1.65)	176	3.59 (1.74)	174	2.79 (1.68)	163
Rehearsal						
0 Months *	4.25 (0.86)	190	3.55 (1.09)	150	2.57 (1.02)	216
3 Months	4.83 (1.42)	226	4.41 (1.61)	214	2.69 (1.46)	238
9 Months	4.68 (1.40)	222	4.53 (1.44)	212	2.66 (1.38)	228
16 Months	4.37 (1.43)	176	4.15 (1.45)	174	2.36 (1.30)	163

* Rehearsal measures were recorded on a 5 point Likert scale for Survey 1 and on a 7 point Likert scale for Surveys 2 (3 months), 3 (9 months) and 4 (16 months).

3.4.1 Effects of Residency and Voting Choice on Emotional Experiences

We expected Remain participants to experience more negative emotions than Leave and U.S. participants. Likewise, we expected that Leave participants would experience more positive emotion than Remain participants and U.S. participants. To test these predictions, levels of current negative and positive emotion were separately analysed using growth curve modelling. Growth curve modelling was performed with levels of negative or positive emotion as the dependent variable and residency (2: U.S., -1: Remain, -1: Leave) and voting choice (1: Remain vs. -1: Leave) as predictors of growth parameters. The analyses revealed that U.S. participants, compared to U.K. participants, had lower initial levels of both negative, β= -.37, t = -10.64, p = < .001, and positive emotion β= -.37, t = -10.35, p < .001, compared to U.K. participants (see Tables 3.2 – 3.3). U.S. participants also had a steeper decline in negative emotion, β = -.02, t = -2.46, p = .014, while they had a similar decline in positive emotion to U.K. participants (p = .78). Thus, consistent with our prediction, our results suggest that U.S. participants experienced more neutral emotion towards the event than U.K. participants.

In addition, within our U.K. participants, Remain participants had higher initial levels of negative emotion, β = 1.53, t = 25.94, p <.001, but lower initial levels of positive emotion, β = -1.77, t = - 28.26, p <.001, compared to Leave participants. Thus, while U.K. participants initially had stronger negative and positive emotional responses than U.S. participants did, negative emotional responses were driven by Remain participants, while positive emotional responses were driven by Leave participants. We also found that Remain participants showed a steeper decline in their negative emotion than Leave participants, β= -.03, t = -2.73, p = .006, though there was no statistically significant difference in the change of positive emotions over time between Remain and Leave participants, p = .06. Nevertheless, Remain participants still reported significantly stronger negative emotion than Leave participants at the last time point (Survey 4), t (393.41) = -19.01, p < .001, d = -1.80, 95% CI [-2.29, -1.86]. Likewise, Leave participants still reported significantly stronger positive emotion than Remain participants at the last time point, t (387.13) = -11.73, p < .001, d = 2.20, 95% CI [-1.61, -1.15]. Taken together, these results support our expectation that Remain participants experienced more negative emotions about the event throughout the four surveys while Leave participants experienced more positive emotions. Thus, our two U.K. voting groups interpreted the event differently in terms of its valence.

3.4.2 Effects of Residency and Voting Choice on Memory

Next, we specified growth curve modelling with SEM to address our main research question: whether three groups of participants showed differences in measures of memory consistency, confidence and vividness over time.

Table 3.3.

Growth Curve Models of Negative and Positive Emotion

	A. Negative Emotion			B. Positive Emotion		
	b (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI
Intercept	3.23 (0.05)***	65.92	3.13 - 3.32	2.68 (0.05) ***	51.99	2.58 - 2.78
US vs UK	-0.37 (0.03)***	-10.64	-0.43 - -0.30	-0.37 (0.04)***	-10.35	-0.45 - -0.30
Remain vs Leave	1.53 (0.06)***	25.94	1.42 - 1.65	-1.77 (0.06)***	-28.26	-1.89 - -1.65
Slope	-0.03 (0.01)**	-3.26	-0.04 - -0.01	-0.02 (0.01)*	-2.21	-0.04 - -0.002
US vs UK	-0.02 (0.01)*	-2.46	-0.03 - -0.003	0.002 (0.01)	0.27	-0.01 - 0.01
Remain vs Leave	-0.03 (0.01)**	-2.73	-0.05 - -0.01	0.02 (0.01)	1.90	-0.001 - 0.04
Correlations						
Intercept ~~ Slope	0.09 (0.26)	0.32	-0.43 - 0.60	-0.14 (0.39)	-0.37	-0.90 - 0.62
Model Fit Indices						
Comparative Fit Index (CFI)		0.970				0.987
Robust Tucker-Lewis Index (TLI)		0.967				0.986
Root Mean Square Error of Approximation (RMSEA)		0.085				0.051

* $p < .05$. ** $p < .01$. *** $p < .001$.

3.4.2.1 Memory consistency

The analysis on consistency revealed that U.K. participants had a higher memory consistency score for Survey 2, β = -.05, $t = -6.79$, $p <.001$, but a steeper decline when compared to U.S. participants, β = .003, $t = 2.03$ $p = .04$ (Figure 3.2). Despite their steeper decline in memory consistency, even at Survey 4, U.K. participants showed more consistent memories than U.S. participants, $t\,(572) = -10.03$, $p < .001$, $d = -.58$, 95% CI [-0.36, -0.24] (Figure 3.3A), supporting our prediction that U.K. participants formed more consistent memories for this political event than U.S. participants.

In addition, while participants in the Leave vs. Remain group were not significantly different in their initial memory consistency level at Survey 2 ($p = .37$), the two voting groups significantly differed in the slope; in other words, Leave participants, relative to

Remain participants, exhibited a quicker rate of decline in memory consistency, β = .01, t = 2.36, p = .02 (see Table 3.4A). To follow up this interaction, we computed simple slopes for each group separately and found that the difference was being driven by a significant decline in memory consistency over time for Leave participants, simple slope = -.01, p = .002, but not for Remain participants, simple slope = -.0001, p = .89. Therefore, despite similar initial levels of memory consistency, Remain participants (who considered the event to be highly negative) maintained more consistent memories about the referendum over time compared to Leave participants (who considered the event to be highly positive).

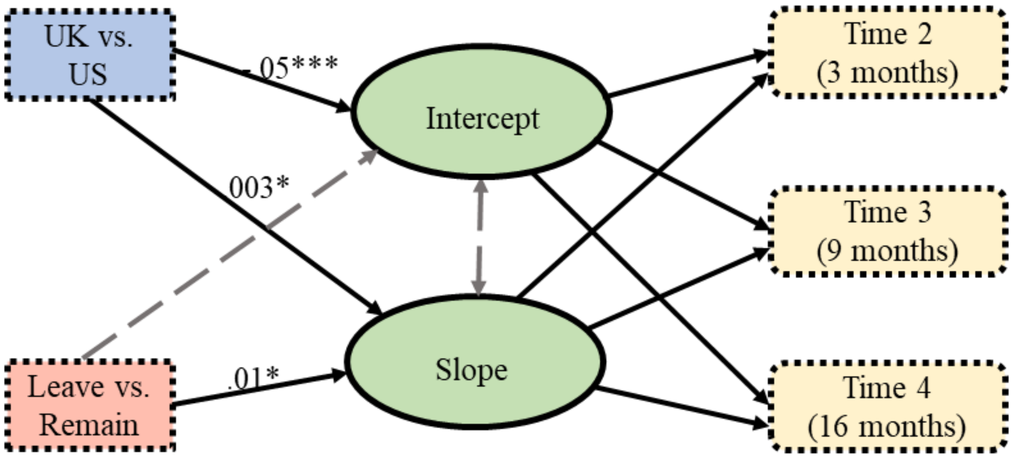

Figure 3.2. Path diagram for memory consistency. The two group variables used orthogonal contrast coding: UK vs US (UK = -1; US = 2) and Leave vs Remain (Leave = -1; Remain =1). Dashed grey lines were nonsignificant paths.

3.4.2.2 Memory confidence

A similar analysis on memory confidence (Table 3.4B) revealed that initial confidence levels at Survey 2 (which is reflected by the intercepts) were higher for U.K. participants compared to U.S. participants, β = -.48, t = -11.03, $p < .001$ (Figure 3.3B). While there were no significant differences between the U.S. and U.K. participants in their slopes (p = .92), these results also support our prediction that U.K. participants tend to have stronger confidence over their memory of the time they found the results of the referendum than do U.S. participants.

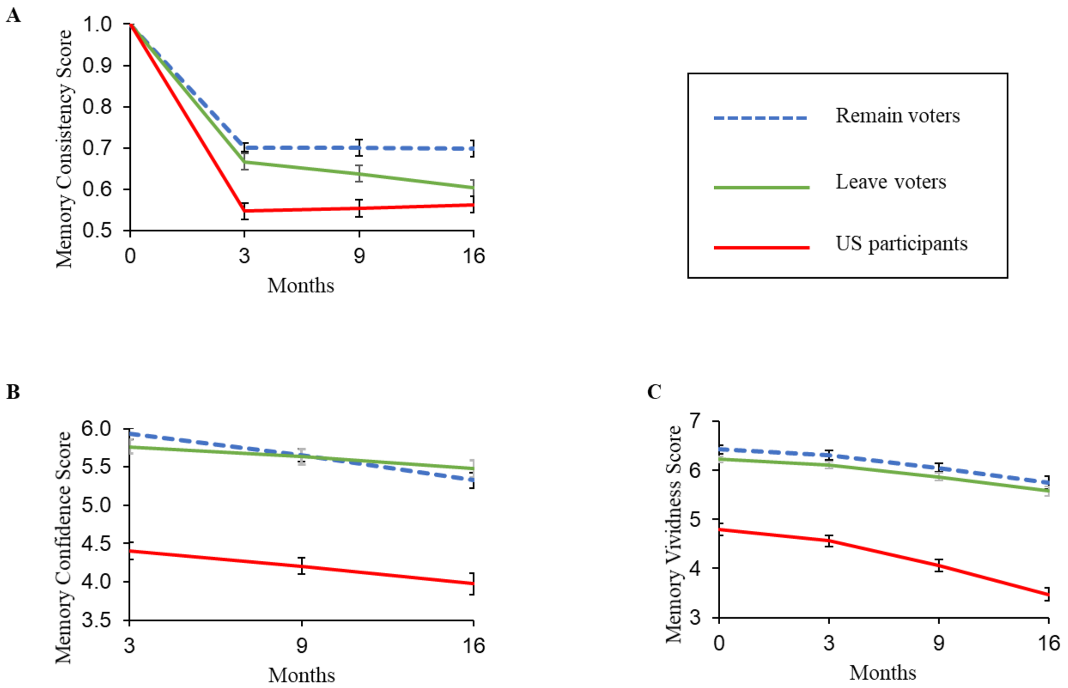

Figure 3.3. Mean ratings for Remain and Leave voters and US participants for (A) memory consistency, (B) memory confidence and (C) memory vividness. Error bars represent standard errors of means.

In addition, we found significant effects of voting choice on the slope, which was in the opposite direction to the memory consistency findings, β = -.03, t = -2.14, p = .03. More specifically, Remain participants exhibited a quicker rate of decline in memory confidence compared to Leave participants. In contrast, the two voting groups were not significantly different in the initial levels of confidence (p =.058). We next computed simple slopes for Leave and Remain participants separately. This simple slope analysis showed that while both Leave and Remain participants showed significant negative slopes, the decline was more pronounced for Remain participants, Leave simple slope = -.06, p = .008; Remain simple slope = -.12, p <.001. These results show that while initial levels of recollection confidence were similar across Remain participants (who reported feeling highly negative after the event) and Leave participants (who reported feeling positive), Leave participants tended to maintain higher levels of confidence over time.

3.4.2.3 Memory vividness

A similar analysis on memory vividness (Table 3.4C) revealed that U.K. participants, compared to U.S. participants, had higher intercepts for their memory vividness, $\beta = -.51$, $t = -13.10$, $p < .001$, with a smaller decline over time (Figure 3.3C), $\beta = -.04$, $t = -4.39$, $p < .001$. As in memory consistency and memory confidence, these results support our prediction that U.K. participants were more likely to have vivid memories for this event than U.S. participants were.

We also found that Remain participants yielded a higher intercept for memory vividness compared to Leave participants, $\beta = .10$, $t = 2.22$, $p = .027$, but had a similar level of decline over time ($p = .88$). Thus, Remain participants initially had more vivid memories than Leave participants. However, this effect was no longer significant when controlling for age, levels of education and gender (see Appendices 3.7, Table A3).

Table 3.4

Growth Curve Models of (A) Memory Consistency, (B) Memory Confidence and (C) Memory Vividness

	A. Memory Consistency			**B. Memory Confidence**			**C. Memory Vividn**	
	b (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI	*b* (SE)	t
Intercept	0.64 (0.01)***	63.35	0.62 - 0.66	5.46 (0.06)***	96.94	5.35 - 5.57	5.82 (0.05)***	1
US vs UK	-0.05 (0.01)***	-6.79	-0.06 - -0.04	-0.48 (0.04)***	-11.03	-0.56 - -0.39	-0.51 (0.04)***	-
Remain vs Leave	0.01 (0.01)	0.86	-0.01 - 0.03	0.12 (0.06)	1.90	-0.004 - 0.24	0.10 (0.05)*	2
Slope	-0.003 (0.002)	-1.48	-0.01 - 0.00	-0.08 (0.01)***	-6.77	-0.11 - -0.06	-0.14 (0.01)***	-
US vs UK	0.003 (0.002)*	2.03	0.00 - 0.01	0.001 (0.01)	0.10	-0.02 - 0.02	-0.04 (0.01)***	-
Remain vs Leave	0.01 (0.002)*	2.36	0.00 - 0.01	-0.03 (0.01)*	-2.14	-0.06 - -0.003	-0.002 (0.01)	-
Correlations								
Intercept ~~ Slope	-0.40 (0.17)*	-2.38	-0.73 - -0.07	0.27 (0.21)	-1.29	-0.67 - 0.14	0.31 (0.30)	1
Model Fit Indices								
Comparative Fit Index (CFI)		0.988		–	0.998		–	0
Robust Tucker-Lewis Index (TLI)		0.965		–	0.995		–	0
Root Mean Square Error of Approximation (RMSEA)		0.047		–	0.021		–	0

* *p* < .05. ** *p* < .01. *** *p* < .001.

3.4.2.4 Effects of Residency and Voting Choice on Changes in Inconsistent Memories over Time

Results reported so far suggest that Remain participants tended to maintain more consistent memories, while Leave participants tended to maintain stronger confidence about their memories despite their less consistent memories (relative to Remain participants). However, these analyses do not tell us changes in the content of inconsistent/incorrect memories over time. Specifically, among participants who had reported an inaccurate memory at Survey 2, some of them reported their inaccurate memory again at Survey 3 ("*repeated"*), whereas others corrected their errors and reported an accurate memory at Survey 3 ("*corrected*"). If negative emotion, experienced by Remain participants, is associated with more accurate memory, Remain participants may show a greater tendency to correct inconsistent memories than Leave participants. To test these issues, next, we examined whether residency and voting choice affects the changes that occurred in inconsistent/inaccurate memories over time.

As done in previous studies (Hirst et al., 2009, 2015), firstly, we focused on inconsistent memories in Survey 2 and then calculated the proportion of memories that were then either corrected, repeated or changed to other errors (if the memory was neither corrected nor repeated) in Survey 3 (see Table 3.5). Proportion scores for corrected, repeated and changed memories were then calculated by dividing the sum of each memory type by the total number of incorrect memories. We then repeated the process but this time, concentrated on inconsistent memories in Survey 3 and calculated the proportion of memories that were then corrected, repeated or changed in Survey 4.

Two separate 3 (Group: Remain vs Leave vs US) X 3 (Memory Type: Repeated vs Corrected vs Changed) Mixed Measures ANOVAs were carried out on these proportion measures to examine how the three groups differed in correcting or repeating their errors. The first ANOVA was carried out on participants who had at least one inconsistent memory in Survey 2 and then later took part in Survey 3, comprising of 86 Leave participants (47 females; age range: 18-82; *M*age = 44.36, SD = 15.72), 109 Remain participants (71 females; age range: 18-83; *M*age = 42.16, SD = 17.75) and 116 U.S. participants (51 females; age range: 18-70; *M*age = 38.12, SD = 13.74). This ANOVA revealed a significant main effect of memory type, $F(2, 616) = 6.71$, $p = .001$, $\eta^2G = 2.13$, without a significant interaction between group and memory type ($p = .97$). Post-hoc analysis using a Bonferroni correction revealed that across all participants, incorrect memories in Survey 2 were more likely to be repeated (*M* = .41, SD = .37) than corrected (*M* = .30, SD = .35, $p < .01$), or changed (*M* = .30, SD = .34, $p < .01$), in Survey 3. There was no significant difference between changed and corrected memories, $p = 1$.

Table 3.5.

Change of inconsistent flashbulb memories from Survey 2 to Survey 3 and from Survey 3 to Survey 4.

Time	Group	Corrected *M* (SD)	Repeated *M* (SD)	Changed *M* (SD)
Survey 2 - 3 *(3-9 months)*	Leave	0.27 (0.37)	0.42 (0.40)	0.31 (0.37)
	Remain	0.30 (0.36)	0.41 (0.39)	0.29 (0.36)
	U.S.	0.31 (0.32)	0.39 (0.33)	0.30 (0.30)
Survey 3 - 4 *(9-16 months)*	Leave	0.30 (0.26)	0.45 (0.37)	0.25 (0.33)
	Remain	0.33 (0.38)	0.40 (0.41)	0.27 (0.38)
	U.S.	0.26 (0.29)	0.42 (0.37)	0.32 (0.33)

The second ANOVA was carried out on participants who had at least one inconsistent memory in Survey 3 and then later took part in Survey 4, including 60 Leave participants (35 females; age range: 18-82; *M*age = 45.90, SD = 15.74), 91 Remain participants (57 females; age range: 19-84; *M*age = 44.74, SD = 18.55) and 73 U.S. participants (35 females; age range: 19-70; *M*age = 39.51, SD = 13.66). Like the previous ANOVA, there was a main effect of memory type, $F(2, 442) = 7.24$, $p <.001$, $\eta^2G = 3.17$, without a significant interaction ($p =.66$). Post-hoc analysis using a Bonferroni correction revealed that once again, there was a greater tendency for participants to repeat ($M = .42$, SD = .39) incorrect memories from Survey 3 in Survey 4 than they were to correct them ($M = .30$, SD = .32, $p = .004$), or change them ($M = .28$, SD = .35, $p = .005$).

Taken together, these findings suggest that incorrect memories were more likely to be *repeated* over time than they were to be *corrected* irrespective of voting choice or residency. Thus, while Remain participants tended to maintain more accurate memories over time than the other two groups, once participants formed inaccurate memories, they tended to simply maintain the inaccurate memories in a stable manner across all groups.

3.4.3 Effects of Residency and Voting Choices on Predictive Factors

The second goal of our study was to examine whether the group differences observed in our memory measures were associated with any of the predictive factors implicated in the formation and maintenance of flashbulb memories (Breslin & Safer, 2011; Day & Ross, 2014; Koppel et al., 2013; Talarico & Moore, 2012; Talarico & Rubin, 2008). Before doing so, we first tested whether the three groups of participants showed any differences in these predictive factors by separately running a series of growth curve modelling for levels of surprise, personal importance, and rehearsal (Table 3.6 A, B and C respectively).

The results show that U.K. participants, compared with U.S. participants, had higher intercepts for surprise, $\beta = -.14$, $t = -3.10$, $p = .002$, personal importance, $\beta = -.80$, $t = -23.69$, $p < .001$, and rehearsal, $\beta = -.67$, $t = -16.70$, $p < .001$. Thus, in general, relative to our U.S. participants, our U.K. participants considered the referendum outcome as more surprising and more personally important, while engaging in more rehearsal. Furthermore, when comparing Leave and Remain participants, we found that Remain participants had higher intercepts for personal importance, β= .16, t = 3.37, p < .001, and rehearsal β = .19, t = 2.58, p =.01, than Leave participants did. However, there was no difference between the two U.K. groups for the intercept of surprise (p = .46). Thus, while both Leave and Remain participants were as equally as surprised by the EU referendum results, our Remain participants initially considered the EU referendum results to be more personally important and engaged in more rehearsal than our Leave participants did. We also found a significant rate of change for U.S. participants when compared with U.K. participants on levels of surprise, β = -.02, t = -2.57, p = .01, and importance, β = -.02, t = -2.45, p = .014, but not for rehearsal (p = .67). These results indicate that U.S. participants, compared to U.K. participants, showed steeper levels of decline in ratings of surprise and importance but similar levels of decline for rehearsal. We did not find any significant rates of change between Remain and Leave participants on levels of surprise, importance or rehearsal.

Table 3.6.

Growth Curve Models of the Predictive Factors (A) Surprise, (B) Rehearsal and (C) Importance

	A. Surprise			**B. Importance**			**C. Rehearsal**		
	b (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI
Intercept	3.80 (0.06)***	58.64	3.68 - 3.93	5.27 (0.04)***	118.45	5.18 - 5.36	4.15 (0.06)***	71.20	4.03 - 4.26
US vs UK	-0.14 (0.04)**	-3.10	-0.22 - -0.05	-0.8 (0.03)***	-23.69	-0.87 - -0.74	-0.67 (0.04)***	-16.70	-0.74 - -0.59
Remain vs Leave	-0.06 (0.08)	-0.74	-0.22 - 0.1	0.16 (0.05)***	3.37	0.07 - 0.26	0.19 (0.07)**	2.58	0.05 - 0.33
Slope	-0.09 (0.01)***	-7.02	-0.12 - -0.07	-0.05 (0.01)***	-5.75	-0.07 - -0.03	-0.09 (0.01)***	-9.18	-0.11 - -0.07
US vs UK	-0.02 (0.01)**	-2.57	-0.04 - -0.01	-0.02 (0.01)***	-2.45	-0.03 - -0.003	0.003 (0.01)	0.42	-0.01 - 0.02
Remain vs Leave	0.01 (0.02)	0.35	-0.03 - 0.04	-0.01 (0.01)	-0.52	-0.02 - 0.01	-0.01 (0.01)	-0.90	-0.03 - 0.01
Correlations									
Intercept ~~ Slope	-0.44 - 0.12	-3.80	-0.66 - -0.21	-0.11 (0.10)	-1.16	-0.30 - 0.08	-0.33 (0.15)*	-2.14	-0.63 - -0.03
Model Fit Indices									
Comparative Fit Index (CFI)	—	0.935		—	0.982		—	0.992	
Robust Tucker-Lewis Index (TLI)	—	0.907		—	0.978		—	0.981	
Root Mean Square Error of Approximation (RMSEA)	—	0.066		—	0.061		—	0.061	

* $p < .05$. ** $p < .01$. *** $p < .001$.

3.4.4 Effects of Predictive Factors on Memory: Mediation Analysis

To address whether positive and negative emotion and any of other predictive factors such as surprise, personal importance and rehearsal are associated with different patterns in memory consistency across Leave vs. Remain participants, we ran a mediation analysis on memory consistency. The mediation effects were tested using the delta method within the *lavaan* package. We found that rehearsal in Survey 1 mediated the relationship between voting group and the changes in memory consistency over time, $\beta = 0.002$, $t = 2.20$, $p = .028$. Specifically, our Remain participants reported greater levels of rehearsal, $\beta = .35$, $t = 6.54$, $p < .001$, and greater levels of rehearsal in turn led to a smaller decline in memory consistency over time (see Table 3.7A; Figure 3.4), $\beta = .01$, $t = 2.31$, $p = .02$. These results indicate that Remain participants maintained memory consistency better than Leave participants over time because they had higher levels of initial rehearsal. We also found that positive emotion in Survey 1 mediated the relationship between voting choice and initial memory consistency, $\beta = 0.03$, $t = 2.36$, $p = .018$. In other words, Leave participants had higher levels of positive emotion at Survey 1, $\beta = -1.74$, $t = -21.73$, $p < .001$, which led to less consistent memories in Survey 2, $\beta = -0.02$, $t = -2.38$, $p = .02$. None of the other predictive factors showed significant effects on the slope or intercept.

Two separate mediation models, one for the growth curve of memory confidence (see Table 3.7B; Figure 3.5) and another for that of memory vividness (see Table 3.7C; Figure 3.6), were also carried out to test the potential mediating effects of the predictive factors on the relationship between voting group and vividness and voting group and confidence. Both models identified personal importance and rehearsal as significant mediators for the effects of residency on the intercepts, $\beta = -0.19$, $t = -3.79$, $p < .001$ and $\beta = -0.12$, $t = -3.47$, $p = .001$, for memory confidence and $\beta = -0.15$, $t = -3.44$, $p = .001$ and $\beta = -0.16$, $t = -6.79$, $p < .001$, for memory vividness. More specifically, compared with U.S. participants, U.K. participants engaged in more rehearsal (memory confidence, β = -.44, t = -15.23, p <.001; memory vividness, β = -.44, t = -15.67, p < .001), and reported higher levels of importance (memory confidence, β = -.77, t = -18.63, p < .001; memory vividness, β = -.77, t = -18.70, p < .001). Higher levels of rehearsal and importance in turn, predicted higher levels of the intercepts both for memory confidence (rehearsal, β = .28, t = 3.53, p = <.001; importance, β = .25, t = 3.86, p < .001) and memory vividness (rehearsal, β = .37, t = 7.63, p < .001; importance, β= .19, t = 3.55, p <.001). These results suggest that higher initial levels of memory confidence and vividness among U.K. participants may be driven by higher levels of perceived importance and stronger engagement in rehearsal.

In addition, we found that the effects of voting choice on the intercept of memory vividness were mediated by three competing effects: a) importance, b) positive emotion, and c) rehearsal. Specifically, relative to Leave participants, Remain participants reported higher levels of importance, β = 0.28, t = 4.68, p <.001, and higher levels of rehearsal, β = .34, t = 6.33 p <.001, both of which in turn predicted higher levels of the intercept for memory vividness (rehearsal, β = .37, t = 7.63, p = <.001; importance, β = .19, t = 3.55, p < .001). At the same time, Leave participants (relative to Remain participants) reported higher levels of positive emotion, β = -1.76, t = -22.13, p <.001, which resulted in *higher* levels of the intercept for memory vividness, β = .09, t = 2.11, p = .035. Thus, while our Leave participants showed lower levels of initial memory vividness than Remain participants in our previous analysis (Table 3.4), this additional analysis suggests that positive emotion experienced by Leave participants did not impair memory vividness; Instead, positive emotion facilitated memory vividness. Our results further indicate that less vivid memories among Leave participants, relative to Remain participants, are driven by the effects of rehearsal and importance.

The models also tested the mediation effects on the slopes of memory confidence and memory vividness but none of the predictive factors were found to be significant mediators on the slope for memory confidence. For memory vividness, personal importance at Survey 1 significantly affected the slope, β= -.03, t = -2.20, p = .03, suggesting that personal importance may mediate the effects of voting choice on changes in memory vividness. However, this mediation effect was not significant, β = -0.01, t = -1.94, p = .052.

Table 3.7.

Predictive Factors as Mediators Between Residency and Voting Choice in (A) Memory Consistency, (B) Memory Confidence and (C) Memory

	A. Memory Consistency			B. Memory Confidence			C. Memory Vividness		
	b (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI
Importance predicted by:									
US vs UK	-0.77 (0.04)***	-18.34	-0.85 - -0.69	-0.77 (0.04)***	-18.63	-0.85 - -0.69	-0.77 (0.04)***	-18.70	-0.85 - -0.69
Remain vs Leave	0.29 (0.06)***	4.84	0.17 - 0.41	0.29 (0.06)***	4.90	0.17 - 0.40	0.28 (0.06)***	4.68	0.16 - 0.39
Negative emotion predicted by:									
US vs UK	-0.39 (0.04)***	-9.12	-0.48 - -0.31	-0.39 (0.04)***	-9.18	-0.48 - -0.31	-0.39 (0.04)***	-9.14	-0.48 - -0.31
Remain vs Leave	1.47 (0.07)***	20.19	1.33 - 1.62	1.47 (0.07)***	20.10	1.32 - 1.61	1.46 (0.07)***	19.97	1.32 - 1.61
Positive emotion predicted by:									
US vs UK	-0.30 (0.04)***	-6.38	-0.39 - -0.20	-0.30 (0.05)***	-6.44	-0.39 - -0.21	-0.30 (0.05)***	-6.44	-0.39 - -0.21
Remain vs Leave	-1.74 (0.08)***	-21.73	-1.90 - -1.59	-1.75 (0.08)***	-22.13	-1.9 - -1.59	-1.76 (0.08)***	-22.13	-1.91 - -1.60
Rehearsal predicted by:									
US vs UK	-0.44 (0.03)***	-14.99	-0.50 - -0.38	-0.44 (0.03)***	-15.23	-0.5 - -0.38	-0.44 (0.03)***	-15.57	-0.50 - -0.39
Remain vs Leave	0.35 (0.05)***	6.54	0.25 - 0.46	0.35 (0.05)***	6.56	0.25 - 0.45	0.34 (0.05)***	6.33	0.23 - 0.44
Surprise predicted by:									
US vs UK	-0.13 (0.05)**	-2.56	-0.23 - -0.03	-0.13 (0.05)**	-2.54	-0.23 - -0.03	-0.13 (0.05)**	-2.56	-0.23 - -0.03
Remain vs Leave	-0.13 (0.10)	-1.34	-0.32 - 0.06	-0.14 (0.10)	-1.37	-0.33 - 0.06	-0.14 (0.10)	-1.46	-0.34 - 0.05
Intercept predicted by:									
Importance	0.01 (0.01)	1.09	-0.01 - 0.03	0.25 (0.06)***	3.86	0.12 - 0.37	0.19 (0.05)***	3.55	0.09 - 0.30
Negative Emotion	0.002 (0.01)	0.28	-0.01 - 0.02	-0.05 (0.05)	-0.85	-0.15 - 0.06	0.05 (0.04)	1.32	-0.03 - 0.13
Positive Emotion	-0.02 (0.01)*	-2.38	-0.03 - -0.003	0.05 (0.05)	1.02	-0.05 - 0.15	0.09 (0.04)*	2.11	0.01 - 0.16
Rehearsal	-0.01 (0.01)	-0.76	-0.03 - 0.01	0.28 (0.08)***	3.53	0.12 - 0.43	0.37 (0.05)***	7.63	0.28 - 0.47
Surprise	0.001 (0.01)	0.18	-0.01 - 0.01	0.05 (0.04)	1.28	-0.03 - 0.12	0.05 (0.03)	1.84	-0.003 - 0.10
US vs UK	-0.05 (0.01)***	-5.03	-0.07 - -0.03	-0.17 (0.06)**	-2.63	-0.29 - -0.04	-0.14 (0.05)**	-2.90	-0.24 - -0.05
Remain vs Leave	-0.03 (0.02)	-1.35	-0.06 - 0.01	0.11 (0.12)	0.98	-0.12 - 0.35	0.003 (0.09)	0.04	-0.17 - 0.17
Slope predicted by:									
Importance	-0.004 (0.002)	-1.83	-0.01 - 0.00	-0.03 (0.02)	-1.43	-0.06 - 0.01	-0.03 (0.01)*	-2.20	-0.05 - -0.003
Negative Emotion	-0.002 (0.002)	-1.25	-0.01 - 0.001	0.02 (0.01)	1.41	-0.01 - 0.05	0.01 (0.01)	-0.001	-0.02 - 0.02
Positive Emotion	0.001 (0.002)	0.65	-0.002 - 0.004	0.02 (0.01)	1.14	-0.01 - 0.04	0.01 (0.01)	0.93	-0.01 - 0.03
Rehearsal	0.01 (0.002)*	2.31	0.001 - 0.01	-0.02 (0.02)	-0.81	-0.06 - 0.02	0.01 (0.01)	0.58	-0.02 - 0.04
Surprise	0.001 (0.001)	-0.01	-0.002 - 0.002	-0.01 (0.01)	-0.61	-0.03 - 0.01	-0.004 (0.01)	-0.53	-0.02 - 0.01
US vs UK	0.002 (0.002)	0.99	-0.002 - 0.01	-0.01 (0.01)	-1.01	-0.04 - 0.01	-0.05 (0.01)***	-4.42	-0.07 - -0.03
Remain vs Leave	0.01 (0.004)**	2.53	0.002 - 0.02	-0.02 (0.03)	-0.69	-0.08 - 0.04	0.02 (0.02)	1.00	-0.02 - 0.06
Model Fit Indices									
Comparative Fit Index (CFI)	–	0.995		–	0.999		–	0.976	
Robust Tucker-Lewis Index (TLI)	–	0.977		–	0.996		–	0.934	
Root Mean Square Error of Approximation (RMSEA)	–	0.043		–	0.016		–	0.063	

* $p < .05$. ** $p <$ *** $p < .001$.

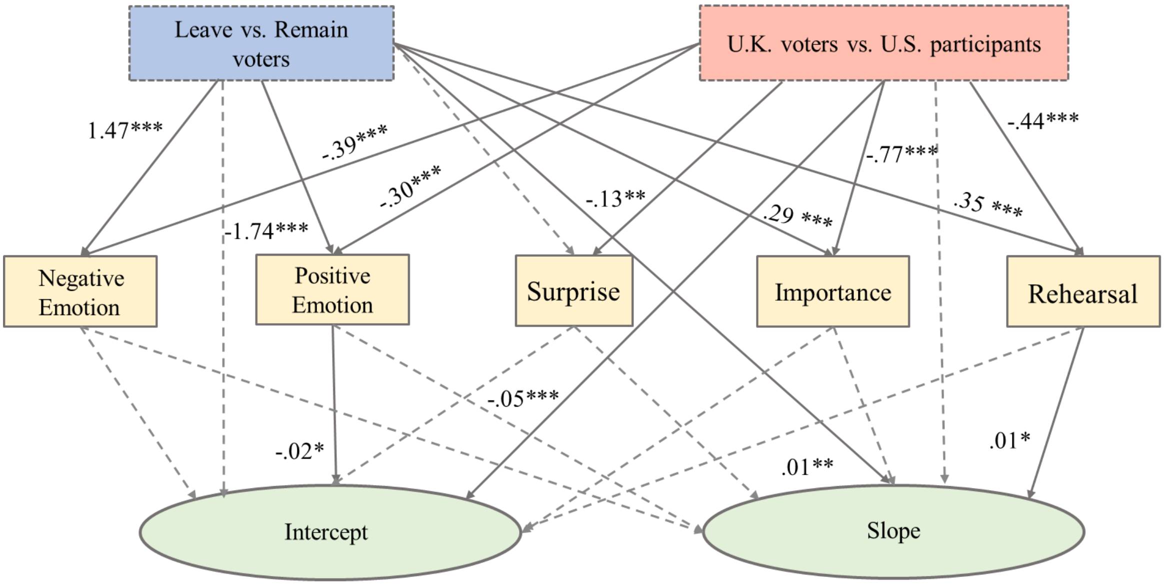

Figure 3.4. Path diagram of the mediation model for memory consistency. The two group variables used orthogonal contrast coding: UK vs US (UK = -1; US = 2) and Leave vs Remain (Leave = -1; Remain =1). Dashed grey lines were nonsignificant paths.

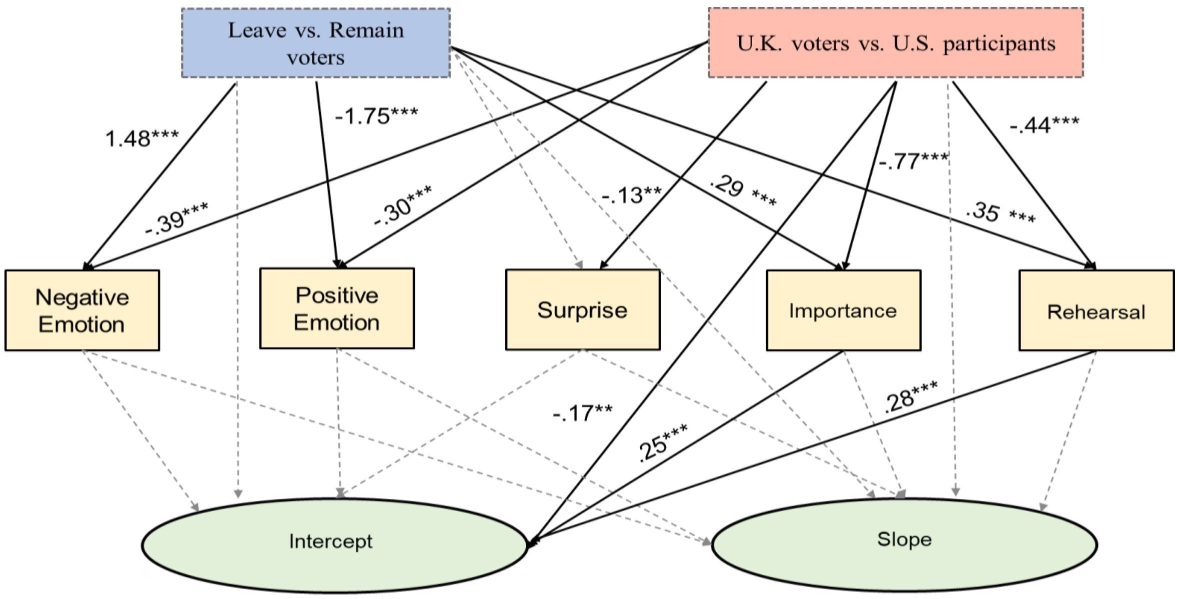

Figure 3.5. Path diagram of the mediation model for memory confidence. The two group variables used orthogonal contrast coding: UK vs US (UK = -1; US = 2) and Leave vs Remain (Leave = -1; Remain =1). Dashed grey lines were nonsignificant paths.

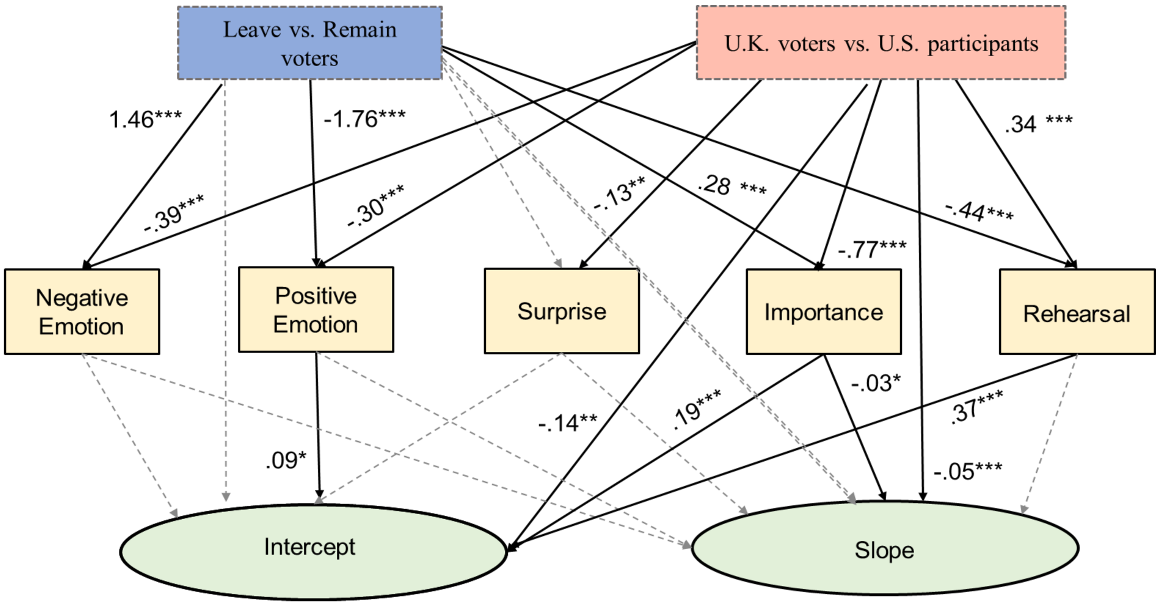

Figure 3.6. Path diagram of the mediation model for memory vividness. The two group variables used orthogonal contrast coding: UK vs US (UK = -1; US = 2) and Leave vs Remain (Leave = -1; Remain =1). Dashed grey lines were nonsignificant paths.

3.5 Discussion

Decades of research has shown that emotion has facilitative effects on memory (Kensinger, 2009a; LaBar & Cabeza, 2006; Mather & Sutherland, 2009; Talmi, 2013) and this is true for older adults too (Charles et al., 2003; Mather, 2004; St. Jacques & Levine, 2007). However, previous research does not provide a clear pattern with regards to the effects of valence. Specifically, research in laboratory settings often demonstrates that negative valence leads to mnemonic advantages over positive valence (Dewhurst & Parry, 2000; Ochsner, 2000), whereas research on autobiographical memories suggests that positive events are remembered better than negative ones (D'Argembeau et al., 2003; Ford et al., 2012; Schaefer & Philippot, 2005; Walker et al., 2003). Research on memories for emotional public events and flashbulb memories also provides mixed evidence on the effects of valence on memory consistency and confidence (Talarico & Rubin, 2017), possibly due to the lack of comparability across surveys in terms of the number of follow-up surveys, the duration between the event and memory assessment and the types of events that are used. On top of this, in the wider emotional memory literature, older adults frequently demonstrate better memory for positive over negative stimuli compared to younger adults (Kennedy et al., 2004; Mather & Carstensen, 2005; Schlagman et al., 2006) however, to date, few flashbulb memory studies have specifically examined the interaction between age and valence on memories for an emotional event (but see Breslin & Safer, 2013).

To address these issues within the literature, in the current study, we examined peoples' memory for the U.K.'s 2016 EU Referendum results. Over four surveys, spanning 16 months, we tested whether memories for the same event differed in the short and long-term measures of memory consistency, vividness and confidence across those who perceived the event to be positive (those who voted to *leave* the EU) and those who perceived the event to be negative (those who voted to *remain* in the EU), and U.S. participants who served as controls. Thus, the current study has advantages in the sense that the same event was used for each valence thereby controlling for potential differences in the characteristics of the event.

Consistent with our hypothesis, the two U.K. groups, compared to their U.S. counterparts, reported higher levels of personal importance, higher engagement in rehearsal (as assessed by thinking, attention to the media and the Internet and through conversations), stronger feelings of surprise, and stronger emotional reactions. The U.K. participants, relative to the U.S. participants, also displayed higher levels of memory consistency, confidence, and vividness, both initially and over time. These findings are consistent with the literature and suggest that flashbulb memories are typically formed for more surprising, emotional and personally important events (R. Brown & Kulik, 1977; M. A. Conway et al., 1994).

According to Berntsen's social identity theory (Berntsen, 2009), when a public event is relevant and important to a particular social group, it can elicit emotional reactions and help sustain rehearsal among its members. This could explain why we found lower levels of memory vividness, confidence and consistency among the U.S. participants because it is unlikely that their social identity, as U.S. participants, was relevant to the U.K.'s EU referendum results. Our findings lend support to previous studies that have found evidence for similar group-level effects (e.g. Berntsen & Thomsen, 2005; R. Brown & Kulik, 1977; M. A. Conway et al., 1994; Curci et al., 2001; Er, 2003; Kvavilashvili et al., 2003) suggest that when facing an emotional, important and surprising public event, individuals from a social group for which the event was relevant, were more likely to form consistent and vivid memories that were recalled with greater confidence.

In addition to the difference between U.K. vs. U.S. participants, we also found that the two U.K. groups showed different reactions to the event; while Remain participants were just as surprised as Leave participants were, Remain participants reported stronger negative emotion and weaker positive emotion as well as higher levels of personal importance, and engaged in rehearsal more than Leave participants did. These two groups also differed in their memory performance. Specifically, Remain participants were initially just as confident and consistent in their memories three months after the referendum results as Leave participants. However, over time, participants who voted to remain became more consistent but less confident in their memory for the EU referendum results than those who voted to leave. This was true even when we re-coded the data to allow for less specific memories and/or memories with more/less detail to be considered *consistent* (see S-Table 4).

These results are consistent with previous findings in which negative emotion has been associated with greater memory consistency and/or event accuracy (Bohn & Berntsen, 2007; Holland & Kensinger, 2012, but see Chiew et al., 2021) and positive emotion has been associated with greater confidence (Chiew et al., 2021; Holland & Kensinger, 2012; Kensinger & Schacter, 2006; Levine & Bluck, 2004). Recent experimental research has also demonstrated that relative to positive emotion, negative emotion enhances the mnemonic precision (Cooper et al., 2019; Xie & Zhang, 2017). One theory which explains this valence effect is the affect-as-information framework (Clore et al., 2001) which suggests that positive and negative valence have differing effects on how we process information; in particular, positive valence is associated with focus on global characteristics of the event and less accurate memory for details, while negative valence is associated with increased sensory details that are stored, maintained and remembered (Bowen et al., 2018). Thus, overconfidence among Leave participants compared to Remain participants and greater memory consistency in Remain participants compared to Leave participants, may be due to the effects of valence on the way these participants processed the event. In line with this idea, in our mediation analysis, we found that higher levels of positive emotion experienced at Survey 1 among Leave participants led to less consistent memory for them than Remain participants. Although we did not find significant effects of negative emotion, these results corroborate previous laboratory findings and suggest that a mnemonic disadvantage of positive relative to negative emotion can be extended to memories for real life events.

In addition to positive emotion, our mediation analysis also highlighted the role of rehearsal. Specifically, higher initial rehearsal levels at Survey 1 among Remain enabled them to maintain more consistent memories even after a long-term delay. Although it has not always been found to predict memory consistency and/or accuracy (Day & Ross, 2014; Hirst et al., 2009; Kensinger, Krendl, et al., 2006; Kvavilashvili et al., 2003; Pillemer, 1984), rehearsal has been implicated as an important factor in maintaining flashbulb memories (Bohannon, 1988; Neisser et al., 1996). In particular, it has often been highlighted in studies examining positive and negative flashbulb memories because positive events are often spontaneously rehearsed more than negative ones (Berntsen & Thomsen, 2005; Breslin & Safer, 2011; Tekcan, 2001; Walker, Skowronski, Gibbons, Vogl, & Ritchie, 2009). While these patterns are the opposite from what we saw in this study (where Leave participants who experienced positive emotion engaged in less rehearsal than Remain participants who experienced negative emotion) similar findings to ours have also recently been observed in a study examining flashbulb memories for the 2016 U.S. Presidential Election in which Clinton supporters reported greater levels of rehearsal compared to Trump supporters (Chiew et al., 2021). Moreover, it is important to note that the effects of valence on rehearsal depend on the conditions after the event, such as increased media attention (Breslin & Safer, 2011). In the U.K. "Brexit"[5] headlines have dominated the news not only in the immediate aftermath of the Referendum but also for several years after. This means that our U.K. participants were likely to have been faced with constant reminders of Brexit irrespective of whether they initially experienced positive or negative emotion. We have shown here that in such situations when the amount of external reminders is similar following an event, negative memories can be initially rehearsed more which could lead to greater memory consistency and higher memory vividness.

In contrast to memory consistency, we did not find any significant mediators for the group differences in the slope of memory confidence ─ a key distinguishing feature of flashbulb memories (Talarico & Rubin, 2003, 2017). More specifically, our initial analysis showed that participants who voted to leave tended to maintain higher confidence for their memory than those who voted to remain (Figure 3.3B). Yet, when we tested the effects of emotional responses, surprise, importance and rehearsal in our mediation analysis, none of them significantly mediated this group effect. This was in contrast with previous findings from Day and Ross (2014) in which memory confidence was associated with surprise, rehearsal, and emotional response. One possible explanation for the lack of significant mediators in our study is that some of the mediators included in the model did play a role but our sample size was too small to detect their effects; in fact, our sample size was determined

[5] An abbreviation for "British exit" used to describe the United Kingdom's decision in 2016 to withdraw its European Union membership.

to have sufficient statistical power to detect the group differences but not to detect such mediation effects (see Participants and Recruitment). But it is also possible that the group difference in memory confidence comes from group differences during retrieval rather than group differences during encoding, such as differences in the ease of retrieval or in the social expectations concerning what one ought to remember (Echterhoff & Hirst, 2006). Future research needs to include a larger number of participants with more comprehensive assessments of factors relevant to retrieval to understand how differently positive vs. negative public events affect memory confidence.

Another important aspect of memory investigated in the literature on emotion and memory is vividness. Our analyses on memory vividness revealed that Leave and Remain participants showed similar rates of decline in their memory vividness over time but Leave participants initially had lower ratings relative to Remain participants. This result may appear to suggest that positive emotion experienced by Leave participants has an impairing effect on memory vividness. However, a subsequent mediation analysis suggested a more complex pattern, indicating that this group difference was due to the competing effects of positive emotion, rehearsal and importance. Specifically, Leave participants experienced stronger positive emotion which in turn significantly led to *more vivid* memories. However, Leave participants also perceived the event as less important and engaged in rehearsal less than Remain participants did, which led to *less vivid* memories. The results were also replicated after including other control variables, such as age and education (see Appendix 3.7.3 for supplemental results).

Contrary to our predictions regarding the effects of age and valence on flashbulb memory measures of consistency, confidence and vividness, we did not find any age-related differences to support the positivity effect in memory for a public emotional event. Instead, our results were more similar to that of Breslin and Safer's (2013) findings. One possibility for not finding support for the positivity effect could be due to the demographics of our participants. When comparing the demographic variables of our three groups (Leave, Remain and U.S. participants), our analysis did show that our groups differed on age, gender and education although post-hoc analyses confirmed that this was not the case when comparing our two U.K. voting groups. However, when looking more closely at chronological age, we arguably had a small sample of older old adults in the study. In fact, while the age of our participants ranged from 18-87, our participant age was heavily skewed to younger participants which may have prevented us from seeing a positivity effect pattern. Across all three groups, individuals who were 65 and above made up between 7-8% (depending on the survey wave) of the sample whereas those who were 60 and above made up between 11 and 13%. More specifically, there were only 17 Leave voters and 32 Remain voters aged 60 and above who took part in Survey 1 and at least one subsequent survey (see Appendix 3.7.3, Table A9 for a breakdown of older Leave and Remain voters at each survey). Although the defined age of older adults varies across studies investigating the positivity effect (see Reed et al., 2014 for a review), the average age of older adults across the studies included in Reed et al.'s meta-analysis was 72.02 years (SD = 3.47). Therefore, we may not have had a sufficient number of older old adults across our groups to evidence the positivity effect.

In summary, we found that positive and negative public events are remembered differently, both initially and after a long-term delay by assessing individuals' memory for the U.K.'s EU Referendum. Remain participants who experienced negative emotion maintained more consistent memories even after 16 months, compared to Leave participants who experienced positive emotion. This difference between the two voting groups appears to be driven not only by differences in their emotional experiences but also by differences in rehearsal. Despite being less consistent, Leave participants maintained higher levels of memory confidence than Remain participants. In addition, we found that positive emotion, rehearsal, and perceived importance all affect how vividly individuals remembered their circumstances in which they found the referendum result. Thus, it appears that memories for emotional public events are supported by several pathways beyond the effects of emotion. Nevertheless, as described above, our sample size was modest for mediation analyses. Thus, results from the series of mediation analyses need to be interpreted with caution; future studies with a larger number of participants are needed to confirm the effects of potential factors observed in this study.

Moreover, we did not find an age-by-valence interaction to support the positivity effect that is frequently seen among older adults. Therefore, future work directly testing the relationship between age and valence on memories for emotional events is required. Depending on the nature of the emotional event/(s), this could be done using a 2 (age: young vs. old adults) X 2 (event valence: positive vs. negative) between subjects design for a single emotional event that is either interpreted as negative or positive with an equal number of younger and older participants in each group. Alternatively, in order to examine the positivity effect within participants, a 2 (age: young vs. old adults) X 2 (event valence: positive vs. negative) mixed measures design could be implemented. While this design allows for a more direct measure of the positivity effect (preference for positive over negative stimuli relative to younger adults), it would require two separate emotional events: one positive and one negative and may be confounded by differences in the event characteristics.

While our results are consistent with previous studies on valence on memory (Kensinger, Garoff-Eaton, & Schacter, 2006; Kensinger & Schacter, 2006; Levine & Bluck, 2004; Ochsner, 2000), it is also possible that they are not necessarily being driven by valence. For instance, while the event was the same for the two U.K. voting groups, the outcome and implications may not have been. According to Brown’s transition theory (2016), an event which is perceived to mark the end to life as it was previously known is effective in facilitating the formation and maintenance of autobiographical memories. For U.K. participants, the result of the referendum indicated possible changes to many things including current legislation, the rights of European Union citizens, public trade practices and immigration rights, to name a few. Participants who voted to remain in the U.K. may have perceived these changes as more significant than those who voted to leave in the U.K. as they are inconsistent with their wishes. In line with this idea, when we asked the perceived changes due to the referendum result in this study ("*Since the EU Referendum results has your life got better, got worse or stayed the same?"*) in Survey 2, Leave participants were more likely to say that their lives had stayed the same compared with Remain participants (92 % vs. 79%; see Appendix 3.7.3 for supplemental results). Thus, Remain participants may have felt that the referendum results had a more direct impact on their current lives than Leave participants did, which may have affected their memory performance. However, it should be noted that previous studies demonstrate consistent, vivid and confident memories for emotional events even when the events are not associated with life transitions. For example, several studies have found evidence of vivid memory formation following sporting events (e.g. Breslin & Safer, 2011; Kensinger & Schacter, 2006; Talarico & Moore, 2012) which are unlikely to have been significant enough to bring about change to an individual's daily life. Future studies need to test the effects of perceived changes, emotional valence and their interaction on memory formation and maintenance to address the role of each factor systematically.

Another factor which may have played a role is arousal or intensity (Chiew et al., 2021). In other words, while valence differed between the two U.K. voting groups, so too could levels of arousal which may affect long-term memory accuracy. Arousing information relative to non-arousing information is consolidated more effectively (LaBar & Phelps, 1998) through the activation of the noradrenergic system and the hippocampal memory formation, resulting in a more stable memory over time (McGaugh, 2000, 2004). Emotional arousal can also lead to selective memory in which the salient/central details of the event are remembered better but at the expense of the non-central details (e.g. central vs. peripheral trade-off; Kensinger, Garoff-Eaton, & Schacter, 2007). Since negative events are often associated with stronger arousal levels or intensity levels than positive events (Chiew et al., 2021; Kuppens, Tuerlinckx, Russell, & Barrett, 2013; Warriner, Kuperman, & Brysbaert, 2013) this may explain why over time, Remain participants held more consistent memories than Leave participants did. However, as we did not obtain measures of arousal in the current study, we do not know whether levels of arousal contributed to the long-term differences in memory consistency. Future research investigating memories for a positive vs. negative event should also include measures of arousal.

There are also several important limitations that need to be mentioned. The first limitation of the current study is that due to its nature, we could not randomly assign participants to the two voting groups or the control group (U.S. participants), meaning that the results may simply reflect the characteristics of the people who voted to *leave* or *remain* in the EU referendum rather than reflecting the effects of valence. In fact, the two groups were significantly different in their age, gender and levels of education. In addition to these demographic variables, another possible factor that could affect our results is the recruitment method. Specifically, Remain participants included more undergraduate students than Leave participants who were often recruited via Prolific. On the one hand, this observation is consistent with the general voting behaviour seen in U.K. residents: U.K. residents with university degrees and those of a younger age were less likely to vote Leave (Alabrese, Becker, Fetzer, & Novy, 2019). In our supplemental analyses, we also confirmed that controlling for age, gender and education did not change our overall results (see Appendix 3.7.3 for supplemental results). Nevertheless, it is possible that the effects of valence we observed are driven by other factors than valence. In addition, the three groups of participants were different in their political orientation; such that Leave participants supported conservative political parties more than Remain participants and U.S. participants. Thus, it is difficult to establish the causal effects of valence and group identity from our results.

Additionally, we do not have a representative sample in our U.K. or U.S. participants and it is possible that we recruited and retained individuals who were more interested in the political consequences of the referendum or those who welcomed the opportunity to share their memories and thoughts (i.e., self-selection bias; Heckman, 1990). In fact, when we compared those who completed Survey 1 and returned in later surveys vs. those who dropped out after completing Survey 1, returning participants reported higher levels of initial rehearsal than those who dropped out. Thus, we may have retained a subset of participants who had stronger commitment to follow up the event. We also found other differences between the two groups of participants in their age, education and positive emotion. Thus, our results are unlikely to represent the effects of voting choice and emotion across all U.K. voters.

Besides the possibility that we retained individuals who were more interested in the consequences of the referendum, it is also the case that some participants completed all four surveys whereas others may have only completed two. In fact, Remain participants completed significantly more surveys compared to US participants. These differences could have important implications in terms of our memory measures since previous research has shown that repeated retrieval can enhance people's memory (Karpicke & Roediger, 2007; Mcdermott, 2006). However, it is reassuring that no significant differences between the number of completed surveys were found between Leave and Remain participants meaning that the differences between these two groups on memory measures are more likely to be driven by the differences in emotion and rehearsal. Nevertheless, future work should consider the possibility that repeated retrievals in flashbulb memory studies could contribute to enhanced memory over time.

Thirdly, we included U.S. participants as a control group based on similar methods used in other studies (e.g. defining groups based on different nationalities; M. A. Conway et al., 1994; Curci et al., 2001; Kvavilashvili et al., 2003; Luminet et al., 2004; Tinti et al., 2009). Having a control group allowed us to test the effects of social identity on memory for the same event (Berntsen, 2018). Yet it is important to acknowledge the differences between U.K. and U.S. participants beyond their social identity. For example, U.K. participants, relative to U.S. participants, may have had a better understanding of the historical background of the referendum, and been exposed to more media coverage of the event. Moreover, we did not control for the time at which participants learnt the EU referendum results. Given the event's political nature, results from each region within the U.K. became available whenever counting of the votes within the region was complete up until the official results across the U.K. were published early the following day. This is potentially problematic when also considering the time difference between the two countries. For many participants in the U.K., the referendum outcome was released in the morning; meaning that they learned of the results right after waking up. In contrast, for those in the U.S., it was more likely that they learned of the results during the evening. Thus, the difference between our U.K. and U.S. participants in their memory measures could have been due to these other factors.

In contrast, one of our main focuses of this paper was to examine the differences between U.K. participants who perceived the event as positive vs. those who perceived the event as negative in their memories. Since both groups of participants lived in the UK, comparisons between these two groups are less likely to be affected by these factors. Nevertheless, some U.K. participants said that they made a conscious effort to watch the results throughout the night; these participants could have learned the results of individual regions first and may have been able to predict the outcome before the results were officially announced. In contrast, others woke up to the news. Between these two sub-groups of participants, levels of surprise may differ, causing differences in the way in which the memories were encoded. In addition, when it came to asking participants questions about where they were and what they were doing etc., participants who stayed up to watch the results, may have provided us with information relating to a different time compared to their initial report. In other words, it is possible that those who monitored the results throughout the night could have two memories regarding the reception event: one for the time before the results were official (i.e., while watching the live footage) and one for after. In the current study, we did not obtain information about whether participants stayed awake all night to monitor the results or not.

Another important question for future research concerns rehearsal. Our measure of rehearsal includes both overt- (e.g., talking to others about it or watching the media) and covert rehearsal (e.g., thinking about it) as well as an item that indicates how much time they spent on the internet. Participants' responses to these four items were highly correlated as indicated by the high internal consistency (see Method). When we separately computed measures on covert (thinking about) vs. overt rehearsal (talking to others about it, watching the media or looking on the internet), they were highly correlated with each other at Survey 1: r (554) = .85, $p < .01$. Thus, it was difficult to test their independent effects on our memory measures in this study. However, other studies have argued that overt rehearsal is associated with more consistent memories than covert rehearsal (Hornstein et al., 2003; Koppel et al., 2013). Moreover, Chiew and colleagues (2021) recently found that their covert rehearsal measure, adapted from the Event-Related Questionnaire (ERQ: Kensinger & Schacter, 2006; "How frequently have you thought about the election outcome?"), was greater among those participants who experienced the highest levels of negative affect (Clinton supporters). However, a similar covert rehearsal measure obtained from the Autobiographical Memory Questionnaire (AMQ: Rubin, Schrauf, & Greenberg, 2003; "I purposely thought about this event") was not differentially associated with valence or political group. Offering a possible explanation for this inconsistency, the authors highlight that the rehearsal measures from the ERQ have not been validated psychometrically like the AMQ has (Chiew et al., 2021). Therefore, future research is needed not only to test the effects of covert and overt rehearsal on memories for positive vs. negative public events but also to test the validity of such rehearsal measures.

Finally, it is also worth noting that over the course of the survey period, the U.K. underwent two significant political events including the official intention of the U.K. to leave the EU within two years (i.e., the triggering of Article 50) on 29th March, 2017 and a general election on 8th June, 2017 in which the current governing party lost its majority, resulting in the formation of a minority government. Both of these events dominated the news and as such may have influenced participants' emotional reactions and/or memories.

In summary, the current study provides evidence that memories surrounding the personal circumstances of a significant event that is either interpreted as positive or negative can be remembered with a great deal of consistency, vividness and confidence over a year later. Furthermore, the results suggest that valence can yield different outcomes on memory measures both in the short- and the long-term, and corroborate previous findings whereby negative emotion has been associated with better memory consistency while positive emotion has been associated with over-confidence (Kensinger & Schacter, 2006). We also found that differences in memory between those who found the event as positive vs. negative are not only due to emotion, but also due to rehearsal and perceived personal importance. Our findings highlight the importance of considering rehearsal, importance and the time between the event and when memory measures are obtained when interpreting how individuals remember public events. However, future work is needed to understand the positivity effect in memories for public emotional events.

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3.7 Appendices

3.7.1 Appendix 1: Table of survey questions that were administered to participants in the study

Table A1

Survey Questions That are Relevant to the Current Analyses

Memory Properties

1) How vividly do you remember the time you became aware of the referendum outcome? ***1.*** *Not very* ***7.*** *Extremely*

2) What time was it when you found out the results?

3) How did you learn the outcome? Please use the box below to give us a little bit more detail about the source (such as the name of the TV programme you watched; the name of the website you checked).

   Multiple choice options: *TV/ Internet/ Friends or Family/ Newspaper/ Radio / Other*

4) Where were you when you found out the results? Please describe in one sentence and be specific.

5) Who else was there when you found out? Please describe in one sentence and be specific.

6) What were you doing beforehand?

7) What did you do immediately after finding out the results?

Follow-Up Surveys 2, 3 and 4 - Additional memory property questions.

8) How confident are you in your overall recollection of when you found out the referendum results? ***1.*** *Not at all –* ***7.*** *Extremely*

Voting Choice

9) Were you eligible to vote in the 2016 U.K.'s EU referendum?

10) How did you vote? *To remain in the EU/ To leave the EU/ I was eligible but did not vote*

Emotional Intensity and Surprise

Current feelings about the EU referendum result.

11) How strongly do you feel the following emotions when you think of the referendum now? ***1.*** *Not at all to* ***7.*** *Very strongly*

   a) Angry, b) Proud, c) Sad, d) Happy, e) Anxious, f) Surprise

Personal Importance

12) How important are the referendum results to you? ***1.** Not important to **7.** Extremely important*

Rehearsal

13) In the past week how closely have you followed the media coverage of the referendum result?

14) Have you thought about the referendum since finding out the results?

15) Have you spent on the internet reading the latest news about the referendum?

16) Have you talked about the referendum with your friends/family and colleagues?

***1.** Rarely or none of the time or less than 1 day; **2.** Some (1 - 2 days); **3.** Occasionally (3 - 4 days); **4.** Most of the time (5 - 6 days); **5.** Daily*

Follow-Up Surveys - Additional rehearsal questions

Survey 2

17) *In the past 3 months... Using the scale below, please select the most appropriate answer **1.** Very little to **7.** A great deal.*

a. How closely have you followed the media coverage of the referendum result?

b. Have you thought about the referendum since finding out the results?

c. Have you spent on the internet reading the latest news about the referendum?

d. Have you talked about the referendum with your friends/family and colleagues?

Survey 3

18) *In the past 9 months.. Using the scale below, please select the most appropriate answer **1.** Very little to **7.** A great deal.*

a. How closely have you followed the media coverage of the referendum result?

b. Have you thought about the referendum since finding out the results?

c. Have you spent on the internet reading the latest news about the referendum?

d. Have you talked about the referendum with your friends/family and colleagues?

Survey 4

19) *In the past 16 months.. Using the scale below, please select the most appropriate answer **1.** Very little to **7.** A great deal*

a. How closely have you followed the media coverage of the referendum result?

b. Have you thought about the referendum since finding out the results?

c. Have you spent on the internet reading the latest news about the referendum?

d. Have you talked about the referendum with your friends/family and colleagues?

Demographics

20) Please enter your age.

21) Where do you currently reside?

22) Please indicate your nationality.

23) Please indicate your gender / sex.

24) Please select your highest level of education.

25) What is your political affiliation? If other, please specify.

a. *Conservative*, b. *Labour*, c. *Scottish National Party*, d. *Liberal Democrats*, e. *The U.K. Independence Party (UKIP)*, f. *Republican (USA)*, g. *Democrat (USA)*, h. *None*, i. *Prefer not to say* and j. *Other*

3.7.2 Appendix 2: Supplemental Materials

Details of Coding

What time was it when you found out the results? For the question "what time was it when you found out the results?" we coded the data in two ways. The first method of coding, the "*specific or average"* coding column recorded the participant's response into a 24-hour format e.g. if the response was "7:30am", then it would be coded as "07:30". The second method, the "*specific or approximate"* coding, translated time entries (numerical or descriptive) that either reflected very precise times (e.g. "7:22am") or more vague times (e.g. "In the morning") into a time category. Since not all responses were written in a time format and often included more descriptive responses such as *"Morning"*, we used the data from this method of coding to create the memory consistency score.

How did you learn the outcome? For the question *"how did you learn the outcome?"* participants were given pre-defined options to choose from (e.g. television, internet, friends and family, newspaper, radio and other). The pre-defined options were then translated into coding categories (e.g. 0-6) which were then compared across time points.

Where were you when you found out the results? For the question "where were you when you found out the results?" we coded the data in three separate ways to record the geographic locations of participants. The first method of coding recorded the *actual site* i.e. if they were at home, at work or school, or if they were commuting etc. For example, if the participant responded "I was at home watching TV", it would have been recorded as 'home'. The second method of coding recorded participant's '*geographic site'* e.g. if they responded - "In London, UK," while the third method of coding recorded the *room location* e.g. "I was in my bedroom". Since most responses did not include highly specific and/or detailed locations mentioning geographic locations and/or specific rooms, we used the '*actual site'* coded data for our memory consistency score.

Who else was there when you found out? For the question "who else was there when you found out the results?" we coded each person category (e.g. 'spouse/lover', 'parent', 'child' etc.) as "1" if they were mentioned or "0" if they were not mentioned.

What were you doing beforehand? For the question "what were you doing beforehand?" we converted each response into a behaviour category (e.g. 'awaking', 'preparing for the day', 'commuting', 'leisure activities' etc.).

What did you do immediately after finding out the results? For the question "what did you do immediately after finding out the results?" we used our *primary* coding score to code the initial behaviour stated rather than our *secondary* and *additional* coding scores which reflected secondary and additional behaviours. Like the previous question, we converted each response into a behaviour category (e.g. 'emoted', 'followed the news, 'communicated', 'preparing for the day' etc.) and then compared these across time points.

3.7.3 Appendix 3: Supplemental Results

Table A2

Correlations of predictive factors in Survey 1

	1	2	3	4	5
1. Rehearsal	-				
2. Personal Importance	0.67***	-			
3. Positive Emotion	0.03	0.20***	-		
4. Negative Emotion	0.47***	0.44***	0.47***	-	
5. Surprise	0.22***	0.21***	0.14**	0.21***	-

3.7.3.1 Differences in Demographic Characteristics across the Three Groups

In order to examine whether there were any group differences on measures of age, sex and level of education, three separate one-way ANOVAs were carried out for each time point using RStudio (v. 1.1.463) and the *stats* (v. 3.6.2) package (R Core Team, 2019).

Age. The age of participants was significantly different between groups at each survey (*p*s < .005). Post-hoc analysis using Bonferroni multiple comparison test revealed that across all surveys, U.S. participants were significantly younger than Leave participants, $p = .004$ p <.001; p <.001; p <.001 (Surveys 1-4 respectively). There were no significant differences between *Leave* and *Remain* participants (*p*s > .05) or between U.S. and *Remain* participants (*p*s >.05).

Gender. The gender distribution for each group across Surveys 1, 2 and 3 was significantly different (*p*s <.05). In Surveys 1, 2 and 3, the Remain group had significantly more female participants: $z = 3.20$, $p = .008$; $z = 3.50$, $p = .003$ and $z = 3.53$, $p = .002$ (Surveys 1-3 respectively) whereas U.S. participants had significantly more males, $z = 4.46$, $p < .001$; $z = 4.17$, $p < .001$ and $z = 2.68$, $p = .045$ (Surveys 1-3 respectively).

Education. The level of education among participants was significantly different between groups at Survey 1, 3 and 4 (*p*s <.001) but not Survey 2[6]. Post-hoc analysis using Bonferroni's multiple comparison test revealed that at Surveys 1, 3 and 4, Remain participants had significantly higher levels of education compared to both Leave and U.S. participants (*p*s < .001). In addition, at Survey 3, U.S. participants had higher levels of education than Leave participants, p =.017.

3.7.3.2 Effects of Residency and Voting Choice on Memory

Since our groups differed significantly on measures of age, education level and gender, we re-ran the SEM models (see Table A3) to ensure that our results were not being driven by group differences in these measures.

Memory consistency. The analysis on memory consistency supported our initial findings in that U.K. participants had a higher memory consistency score for Survey 2, β = -.05, t = -6.79, p <.001, even after controlling for gender, age and education, β = -.05, t = -6.16, p <.001 (Table A3 A). Likewise, Leave and Remain participants did not significantly differ in their initial memory consistency level at Survey 2 (p = .69), but significantly differed in the slope, β = .01, t = 1.99, p = .046, suggesting that once again, Leave participants exhibited a quicker rate of decline in memory consistency. These results support our initial findings even after controlling for age, gender and education level. However, one difference between the current results and our initial findings is that after controlling for age, gender and education, we no longer find a significant difference in the slope between U.K. and U.S. residents.

[6] Due to a technical error in Survey 2, we do not have education level information for 67% Leave participants, 79% for Remain participants and 77% for U.S. participants. This could therefore explain the non-significant findings.

Memory confidence. A similar analysis on memory confidence (Table A3 B) also confirmed our previous findings. Once again, initial confidence levels at Survey 2 (as reflected by the intercepts) were higher for U.K. participants compared to U.S. participants, $\beta = -.47$, $t = -10.13$, $p < .001$. Furthermore, there were no significant differences between the U.S. and U.K. participants in their slopes ($p = .46$) but there was a significant effect of voting choice, $\beta = -.05$, $t = -3.34$, $p = .001$, suggesting that Remain participants exhibited a quicker rate of decline in memory confidence compared to Leave participants. In addition, the two voting groups were not significantly different in the initial levels of confidence ($p = .05$). Like memory consistency, these results for memory confidence offer further support to our initial findings, even after controlling for age, gender and education.

Memory vividness. A similar analysis on memory vividness (Table A3 C) partially confirmed our initial results. Like before, the results revealed that U.K. participants, compared to U.S. participants, had higher intercepts for their memory vividness, $\beta = -.50$, $t = -12.36$, $p < .001$, with a smaller decline over time, $\beta = -.03$, $t = -3.84$, $p < .001$. We also confirmed that Leave and Remain participants exhibited a similar level of decline over time ($p = .60$). However, unlike our previous findings, after controlling for age, gender and education level, we no longer found a significant difference in the intercept for memory vividness between Leave and Remain participants, $\beta = .07$, $t = 1.29$, $p = .20$. Thus, it seems that after controlling for age, gender and education level, Remain and Leave voters recall memories that are equally as vivid, both initially and across a period of 16 months.

3.7.3.3 Mediation Analysis Including Age, Education and Gender as Covariates

We also re-ran the mediation models while including these demographic variables as covariates (see Table A4). Across all three mediation models, after controlling for age, education level and gender, we replicated our initial findings for memory consistency (Table

A4 A), memory confidence (Table A4 B) and memory vividness (Table A4 C), suggesting that the effects of group were not being driven by the significant differences in the demographic variables.

Table A3

Growth Curve Models of (A) Memory Consistency, (B) Memory Confidence and (C) Memory Vividness After Controlling for Age, Education and Gender.

	A. Memory Consistency			**B. Memory Confidence**			**C. Memory Vividness**		
	b (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI
Intercept	0.56 (0.06)***	9.76	0.45 - 0.67	5.38 (0.36)***	15.02	4.68 - 6.08	5.55 (0.29)***	19.41	4.99 - 6.11
US vs UK	-0.05 (0.01)***	-6.16	-0.06 - -0.03	-0.47 (0.05)***	-10.13	-0.57 - -0.38	-0.5 (0.04)***	-12.36	-0.58 - -0.42
Remain vs Leave	0.01 (0.01)	0.39	-0.02 - 0.03	0.14 (0.07)*	1.96	0.00 - 0.28	0.07 (0.05)	1.29	-0.04 - 0.18
Age	0.002 (0.01)	0.26	-0.01 - 0.02	0.01 (0.004)	1.83	-0.001 - 0.02	0.002 (0.003)	0.63	-0.004 - 0.01
Education	0.01 (0.01)	0.87	-0.01 - 0.03	-0.03 (0.07)	-0.38	-0.16 - 0.11	0.08 (0.06)	1.44	-0.03 - 0.19
Gender	0.03 (0.02)	1.26	-0.02 - 0.07	-0.08 (0.14)	-0.55	-0.36 - 0.20	-0.07 (0.11)	-0.62	-0.28 - 0.15
Slope	0.002 (0.01)	0.15	-0.02 - 0.03	-0.32 (0.08)***	-3.89	-0.48 - -0.16	-0.22 (0.08)**	-2.89	-0.37 - -0.07
US vs UK	0.003 (0.002)	1.83	0.00 - 0.01	0.01 (0.01)	0.74	-0.01 - 0.03	-0.03 (0.01)***	-3.84	-0.05 - -0.02
Remain vs Leave	0.01 (0.003)*	2.00	0.00 - 0.01	-0.05 (0.02)***	-3.34	-0.08 - -0.02	-0.01 (0.01)	-0.53	-0.04 - 0.02
Age	-0.002 (0.001)	-1.29	-0.01 - 0.001	0.00 (0.001)	0.41	-0.001 - 0.002	0.001 (0.001)	1.18	-0.001 - 0.003
Education	0.001 (0.002)	0.42	-0.003 - 0.01	0.05 (0.02)**	3.07	0.02 - 0.08	0.01 (0.01)	1.00	-0.01 - 0.04
Gender	0.00 (0.004)	-0.11	-0.01 - 0.01	0.03 (0.03)	0.84	-0.04 - 0.09	-0.01 (0.03)	-0.34	-0.06 - 0.04
Correlations									
Intercept ~~ Slope	-0.41 (0.18)	-2.29	-0.76 - -0.06	-0.27 (0.24)	-1.14	-0.73 - 0.19	0.27 (0.32)	0.90	-0.30 - 0.87
Model Fit Indices									
Comparative Fit Index (CFI)		0.946		−	0.975		−	0.937	
Robust Tucker-Lewis Index (TLI)		0.853		−	0.934		−	0.890	
Root Mean Square Error of Approximation (RMSEA)		0.066		−	0.050		−	0.072	

* *p* < .05. ** *p* < .01. *** *p* < .001.

Table A4

Predictive Factors as Mediators Between Residency and Voting Choice in (A) Memory Consistency, (B) Memory Confidence and (C) Memory Vividness After Controlling for Age, Education and Gender.

	A. Memory Consistency			**B. Memory Confidence**			**C. Memory Vividness**		
	b (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI	*b* (SE)	t-value	95% CI
Importance predicted by:									
US vs UK	-0.74 (0.04)***	-17.34	-0.82 - -0.65	-0.73 (0.04)***	-17.66	-0.81 - -0.65	-0.73 (0.04)***	-17.69	-0.82 - -0.65
Remain vs Leave	0.22 (0.07)***	3.25	0.09 - 0.35	0.22 (0.07)***	3.29	0.09 - 0.35	0.20 (0.07)**	3.08	0.07 - 0.33
Age	0.08 (0.04)*	2.36	0.01 - 0.15	0.01 (0.003)*	2.33	0.001 - 0.02	0.01 (0.04)*	2.37	0.01 - 0.15
Education	0.16 (0.06)**	2.89	0.05 - 0.27	0.16 (0.06)**	2.84	0.05 - 0.26	0.16 (0.06)**	2.88	0.05 - 0.27
Gender	0.07 (0.11)	0.65	-0.15 - 0.30	0.08 (0.11)	0.66	-0.15 - 0.30	0.08 (0.11)	0.66	-0.15 - 0.30
Negative emotion predicted by:									
US vs UK	-0.36 (0.04)***	-8.18	-0.45 - -0.27	-0.36 (0.04)***	-8.24	-0.45 - -0.27	-0.36 (0.04)***	-8.20	-0.45 - -0.27
Remain vs Leave	1.37 (0.08)***	17.28	1.22 - 1.53	1.37 (0.08)***	17.24	1.21 - 1.52	1.36 (0.08)***	17.06	1.21 - 1.52
Age	-0.08 (0.04)*	-2.03	-0.15 - -0.003	-0.01 (0.004)*	-2.05	-0.02 - 0.00	-0.01 (0.04)*	-2.03	-0.15 - -0.003
Education	0.18 (0.06)**	2.93	0.06 - 0.31	0.18 (0.06)**	2.92	0.06 - 0.31	0.18 (0.06)**	2.92	0.06 - 0.31
Gender	0.35 (0.13)**	2.78	0.10 - 0.60	0.35 (0.13)**	2.79	0.10 - 0.60	0.35 (0.13)**	2.79	0.11 - 0.60
Positive emotion predicted by:									
US vs UK	-0.30 (0.05)***	-6.29	-0.40 - -0.21	-0.30 (0.05)***	-6.37	-0.39 - -0.21	-0.30 (0.05)***	-6.36	-0.40 - -0.21
Remain vs Leave	-1.67 (0.09)***	-19.19	-1.85 - -1.50	-1.68 (0.09)***	-19.50	-1.85 - -1.51	-1.69 (0.09)***	-19.52	-1.86 - -1.52
Age	0.13 (0.04)**	3.01	0.04 - 0.21	0.01 (0.004)**	2.99	0.004 - 0.02	0.01 (0.04)**	3.02	0.04 - 0.21
Education	-0.12 (0.06)*	-1.95	-0.23 - 0.00	-0.12 (0.06)*	-1.98	-0.23 - -0.001	-0.12 (0.06)*	-1.95	-0.23 - 0.001
Gender	-0.18 (0.13)	-1.41	-0.43 - 0.07	-0.18 (0.13)	-1.40	-0.43 - 0.07	-0.18 (0.13)	-1.40	-0.43 - 0.07
Rehearsal predicted by:									
US vs UK	-0.42 (0.03)***	-13.68	-0.48 - -0.36	-0.42 (0.03)***	-13.88	-0.47 - -0.36	-0.42 (0.03)***	-14.13	-0.48 - -0.36
Remain vs Leave	0.27 (0.06)***	4.66	0.16 - 0.39	0.27 (0.06)***	4.68	0.16 - 0.38	0.26 (0.06)***	4.43	0.14 - 0.37
Age	0.05 (0.03)	1.83	-0.004 - 0.11	0.01 (0.003)	1.79	0.00 - 0.01	0.01 (0.03)	1.84	-0.003 - 0.11
Education	0.19 (0.04)***	4.60	0.11 - 0.27	0.19 (0.04)***	4.56	0.11 - 0.27	0.19 (0.04)***	4.66	0.11 - 0.27
Gender	-0.11 (0.09)	-1.28	-0.28 - 0.06	-0.11 (0.09)	-1.29	-0.28 - 0.06	-0.11 (0.09)	-1.27	-0.27 - 0.06
Surprise predicted by:									
US vs UK	-0.12 (0.05)*	-2.19	-0.23 - -0.01	-0.12 (0.05)*	-2.18	-0.22 - -0.01	-0.12 (0.05)*	-2.20	-0.22 - -0.01
Remain vs Leave	-0.09 (0.10)	-0.86	-0.29 - 0.11	-0.09 (0.10)	-0.87	-0.29 - 0.11	-0.10 (0.10)	-0.96	-0.30 - 0.10
Age	0.11 (0.05)*	2.09	0.01 - 0.20	0.01 (0.01)*	2.07	0.001 - 0.02	0.01 (0.01)*	2.09	0.01 - 0.20
Education	-0.08 (0.08)	-1.06	-0.23 - 0.07	-0.08 (0.08)	-1.09	-0.23 - 0.07	-0.08 (0.08)	-1.07	-0.23 - 0.07
Gender	0.11 (0.16)	0.72	-0.19 - 0.42	0.11 (0.16)	0.73	-0.19 - 0.42	0.11 (0.16)	0.73	-0.19 - 0.42
Intercept predicted by:									
Importance	0.01 (0.01)	0.96	-0.01 - 0.03	0.25 (0.06)***	3.89	0.12 - 0.38	0.20 (0.06)***	3.60	0.09 - 0.30
Positive Emotion	-0.02 (0.01)*	-2.31	-0.04 - -0.003	0.04 (0.05)	0.86	-0.06 - 0.15	0.09 (0.04)*	2.11	0.01 - 0.16
Negative Emotion	0.002 (0.01)	0.23	-0.01 - 0.02	-0.03 (0.06)	-0.60	-0.14 - 0.08	0.05 (0.04)	1.31	-0.03 - 0.13
Rehearsal	-0.01 (0.01)	-0.74	-0.03 - 0.01	0.29 (0.08)***	3.67	0.14 - 0.45	0.37 (0.05)***	7.53	0.28 - 0.47
Surprise	0.001 (0.01)	0.10	-0.01 - 0.01	0.04 (0.04)	1.11	-0.03 - 0.11	0.05 (0.03)	1.90	-0.001 - 0.10
Age	0.003 (0.01)	0.52	-0.01 - 0.02	0.003 (0.004)	0.81	-0.01 - 0.01	-0.003 (0.003)	-0.92	-0.08 - 0.03
Gender	0.02 (0.02)	1.02	-0.02 - 0.06	-0.05 (0.14)	-0.35	-0.32 - 0.23	-0.05 (0.09)	-0.53	-0.23 - 0.13
Education	0.01 (0.01)	0.56	-0.02 - 0.03	-0.10 (0.07)	-1.56	-0.23 - 0.03	-0.02 (0.05)	-0.33	-0.12 - 0.08
US vs UK	-0.05 (0.01)***	-4.86	-0.07 - -0.03	-0.17 (0.06)**	-2.58	-0.29 - -0.04	-0.15 (0.05)**	-3.01	-0.24 - -0.05
Remain vs Leave	-0.03 (0.02)	-1.44	-0.07 - 0.01	0.13 (0.12)	1.10	-0.10 - 0.36	0.01 (0.09)	0.10	-0.16 - 0.18
Slope predicted by:									
Importance	-0.004 (0.002)	-1.81	-0.01 - 0.00	-0.03 (0.02)	-1.61	-0.06 - 0.01	-0.03 (0.01)*	-2.30	-0.05 - -0.004
Positive Emotion	0.001 (0.002)	0.78	-0.002 - 0.004	0.02 (0.01)	1.27	-0.01 - 0.04	0.01 (0.01)	0.90	-0.01 - 0.03
Negative Emotion	-0.003 (0.002)	-1.45	-0.01 - 0.001	0.02 (0.01)	1.07	-0.01 - 0.04	0.00 (0.01)	-0.01	-0.02 - 0.02
Rehearsal	0.01 (0.002)*	2.19	0.001 - 0.01	-0.03 (0.02)	-1.25	-0.07 - 0.02	0.004 (0.01)	0.27	-0.02 - 0.03
Surprise	0.00 (0.001)	0.26	-0.002 - 0.003	-0.004 (0.01)	-0.43	-0.02 - 0.02	-0.004 (0.01)	-0.52	-0.02 - 0.01
Age	-0.002 (0.001)	-1.45	-0.01 - 0.001	0.001 (0.001)	0.60	-0.001 - 0.002	0.001 (0.001)	1.20	-0.01 - 0.03
Gender	0.001 (0.004)	0.32	-0.01 - 0.01	0.02 (0.03)	0.68	-0.04 - 0.09	-0.01 (0.03)	-0.23	-0.06 - 0.05
Education	0.001 (0.002)	0.64	-0.003 - 0.01	0.05 (0.02)***	3.39	0.02 - 0.08	0.02 (0.01)	1.33	-0.01 - 0.05
US vs UK	0.002 (0.002)	0.89	-0.002 - 0.01	-0.01 (0.01)	-0.98	-0.04 - 0.01	-0.05 (0.01)***	-4.34	-0.07 - -0.03
Remain vs Leave	0.01 (0.004)**	2.57	0.002 - 0.02	-0.03 (0.03)	-1.13	-0.09 - 0.02	0.01 (0.02)	0.64	-0.03 - 0.06
Model Fit Indices									
Comparative Fit Index (CFI)		0.986		–	0.991		–	0.973	
Robust Tucker-Lewis Index (TLI)		0.932		–	0.955		–	0.974	
Root Mean Square Error of Approximation (RMSEA)		0.059		–	0.042		–	0.058	

* *p* < .05. ** *p* < .01. *** p < .001.

3.7.3.4 Recoded Memory Consistency

A second memory consistency score was obtained, this time using a combination of the Hirst et al. (2009) and the Neisser and Harsch (1992) coding scheme. Here, we focused on responses that had originally received a “0” for the initial consistency score but this time allowed memories that were less specific and/or with more/less detail than previously documented, to be considered *consistent.* In other words, if the responses were initially deemed inconsistent but matched the gist of the initial memory, with more or less detail than before, they were now assigned a “1” to reflect consistency. On the other hand, if they were completely different, absent or did not answer the question, the response received a “0”. Responses that were initially consistent maintained a “1”. Thus, a secondary consistency score, more similar to that of Neisser and Harsch (1992), was created. Similar to the memory consistency score reported in the main text, the recoded memory consistency score was the averaged memory consistency of the 6 recoded questions (Table A1, Questions 2-7) and ranged from 0 to 1.

Another SEM model was carried out with the recoded memory consistency score as the dependent variable (see Table A5). Once again, effect coding was used to create two group variables; one to compare U.K. participants (Leave and Remain voters) with U.S. participants (referred to as *U.K. vs U.S.* in the model) and the second to compare Remain voters with Leave voters (referred to as *R vs L* in the model). The analysis revealed that, like before, U.K. participants had a higher memory consistency score for Survey 2, $\beta = -.04$, $t = -6.38$, $p < .001$, but this time, did not have a steeper decline when compared to U.S. participants, $p = .097$ (Table A5). More importantly, we again found that while Leave and Remain voters were not significantly different in their initial memory consistency level at Survey 2 ($p = .25$), they did significantly differ in the slope; Leave participants exhibited a quicker rate of decline in memory consistency, $\beta = .01$, $t = 2.61$, $p = .009$ (Table A5). These results suggest that the effects of valence we found in our main analyses are not due to the way we coded our memory data.

Table A5

Growth Curve Model (SEM) for Recoded Memory Consistency

	b (SE)	t-value	95% CI
Intercept	0.70 (0.01)***	74.07	0.68 - 0.71
U.S. vs U.K.	-0.04 (0.01)***	-6.38	-0.06 - -0.03
Remain vs Leave	0.01 (0.01)	1.15	-0.01 - 0.03
Slope	-0.003 (0.002)	-1.40	-0.01 - 0.001
U.S. vs U.K.	0.003 (0.002)	1.66	0.00 - 0.01
Remain vs Leave	0.01 (0.002)**	2.61	0.002 - 0.01
Correlations			
Intercept ~~ Slope	-0.49 (0.12)***	-4.07	-0.73 - -0.25
Model Fit Indices			
Comparative Fit Index (CFI)		0.997	
Robust Tucker-Lewis Index (TLI)		0.991	
Root Mean Square Error of Approximation (RMSEA)		0.024	

* $p < .05$. ** $p < .01$. *** $p < .001$.

<u>*3.7.3.5 Memory for Emotional Reactions*</u>

Since previous research has suggested that memories for emotional responses tend to be less accurate than memories for other aspects (Hirst et al., 2009), we also asked participants about their memory of their emotional reactions (emotional intensity and surprise) from when they found the results of the referendum (Table A6 Questions 1a-1f; angry, sad, anxious, happy, proud and surprise all with 7-point Likert scales). We created two measures of emotion for each time point; one to reflect memory of negative emotion and another to reflect memory of positive emotion and separately used measures of surprise (see Table A7 for group means and standard deviations).

Table A6

Emotional Memory Questions that are relevant to the current analyses

Emotional memory

1) How strongly did you feel the following emotions when you found out the results? (1. Not at all to 7. Very strongly)

a. Angry	c. Sad	e. Anxious
b. Surprise	d. Happy	f. Proud

We then explored the effects of voting choice and residency on memory for initial emotional reactions; thus three SEM analyses (similar to the one used for current levels of positive and negative emotion) were performed separately on participants' memory for how negatively or positively they felt and how surprised they felt after learning the referendum results.

As is evident in Table A8 A-B, Remain participants had higher intercepts for memory of negative emotion compared to Leave participants, $\beta = 1.84$, $t = 37.61$, $p < .001$ but lower intercepts for memory of positive emotion, $\beta = -2.04$, $t = 37.01$, $p < .001$. U.K. participants, compared to U.S. participants, had higher intercepts of both negative emotion, $\beta = -0.34$, $t = -9.96$, $p < .001$ and positive emotion, $\beta = -0.38$, $t = -10.75$, $p < .001$. While all groups seemed to forget their initial levels of positive and negative emotion over time, there were no significant differences in the how quickly they forgot negative (U.K. vs US, $p = .25$; Leave vs Remain, $p = .17$) or positive emotion (U.K. vs US, $p = .57$; Leave vs Remain, $p = .62$). Together, these results suggest that memory for the intensity of positive and negative affect, at the time of learning the referendum results, was forgotten at a similar rate for all participants, irrespective of voting choice or residency.

Table A7

Memory of Negative Emotion and Memory of Surprise as a Function of Voting Group and Residency, Across All Surveys

Memory assessments and survey	*Remain*		*Leave*		*U.S.*	
	M (SD)	*n*	*M* (SD)	*n*	*M* (SD)	*n*
Memory for Negative Emotion						
Survey 1	5.61 (1.23)	190	2.05 (1.15)	153	2.80 (1.58)	217
Survey 2	5.58 (1.18)	226	1.93 (1.09)	214	2.63 (1.48)	238
Survey 3	5.57 (1.25)	222	1.92 (1.1)	212	2.72 (1.64)	228
Survey 4	5.43 (1.3)	176	1.85 (0.96)	174	2.59 (1.59)	163
Memory for Positive Emotion						
Survey 1	1.18 (0.59)	190	5.14 (1.76)	153	2.26 (1.69)	217
Survey 2	1.29 (0.66)	226	5.31 (1.69)	214	2.10 (1.55)	238
Survey 3	1.31 (0.69)	222	5.51 (1.63)	212	2.12 (1.61)	228
Survey 4	1.28 (0.62)	176	5.38 (1.56)	174	2.02 (1.60)	163
Memory for Surprise						
Survey 1	5.57 (1.57)	190	5.33 (1.7)	153	5.35 (1.52)	217
Survey 2	5.78 (1.39)	226	5.23 (1.83)	214	5.20 (1.65)	238
Survey 3	5.65 (1.44)	222	5.29 (1.64)	212	5.12 (1.76)	228
Survey 4	5.68 (1.38)	176	5.31 (1.63)	174	4.98 (1.84)	163

As for participants' memory for how surprised they were, U.K. and U.S. participants recalled feeling just as surprised (p = .086) but Remain participants recalled feeling more surprised than Leave voters, β= .21, t = 2.97, p = .003 (see Table A8 C). Unlike the results for memory of negative and positive emotion where all groups showed a similar rate of decline over time, the results for memory of surprise suggests that U.S. participants forgot their initial levels of surprise more quickly over time compared to U.K. participants, β= -.02, t = -2.51, p = .012. However, there were no differences in the rate of change over time between the two U.K. voting groups (p = .87) suggesting that they forgot their initial levels of surprise at a similar rate.

Previous research has argued that emotional reactions are forgotten more quickly than levels of consistency, confidence and vividness (Hirst et al., 2009, 2015). Past research has also shown that memories for emotional reactions can be influenced by our current emotional state (Levine et al., 2001, 2005) and that post-event information can encourage us to under- or over-estimate our past emotions (Safer et al., 2002). Consistent with these prior findings, we found that participants' memory for their initial reaction of surprise declined over time for all groups of participants but especially for U.S. participants. These findings fit with the idea that individuals use their current emotional states when remembering past emotional experiences (Levine & Safer, 2002). In other words, they are more likely to recall past emotions that are more consistent with their current feelings. In contrast, we did not find a significant effect of time for how negative or positive participants originally felt, indicating that all groups forgot their initial emotional reactions at a similar rate over time. Interestingly, when we analysed their current levels of negative and positive emotion, these emotions declined with time suggesting that memory for them does not seem to be biased by current feelings. Although this finding is contrary to previous research which has found that past emotions are often over- or under-estimated depending on the current appraisal of the event (Levine et al., 2001; Safer et al., 2002) or that they are forgotten more quickly than other features of a flashbulb memory (Hirst et al., 2009), it could be that we have not yet seen evidence of this bias and/or effect within our timeframe of 16 months, especially as there was also no official outcome of the referendum vote within this time. Once again, these results may be specific to this particular event and as such, future research should further investigate the consistency of memory for past emotional reactions.

3.7.3.6 Perception of change to life

In Surveys 2 we asked "*Since the referendum results, has your life got better, got worse or stayed the same?"* and participants were asked to choose one of the three options (a) "*got better",* (b) "*got worse"* or (c) "*stayed the same".* A chi-square test of independence was performed to examine the relationship between group (Remain vs. Leave participants) and the perception of change to life (changed: better or worse vs. stayed the same)[7]. We found that the two groups significantly differed in their perception of change to their lives since the referendum results, $\chi2$ (1) = 11.09, $p < .001$. In Survey 2, 21% of Remain participants said that their life had changed (got better or worse) compared to only 8% of Leave participants. These results suggest that participants may have differed in their perception of how much the EU referendum results changed their lives.

[7] The cell sizes for *"got better"* and *"got worse"* were smaller than 5, therefore we combined these two measures into one variable to represent *"change".*

Table A8

Growth Curve Models of (A) Memory of Negative Emotion and (B) Memory of Surprise

	A. Memory of Negative Emotion			B. Memory of Positive Emotion			C. Memory of Surprise		
	b (SE)	t-value	95% CI	b (SE)	t-value	95% CI	b (SE)	t-value	95% CI
Intercept	1.25 (0.09)***	77.55	3.35 - 3.53	2.92 (0.05)***	60.84	2.83 - 3.02	5.43 (0.06)***	97.60	5.32 - 5.54
US vs UK	-0.34 (0.03)***	-9.96	-0.41 - -0.27	-0.38 (0.04)***	-10.75	-0.46 - -0.3	-0.07 (0.04)	-1.71	-0.14 - 0.01
Remain vs Leave	1.84 (0.05)***	37.61	1.74 - 1.93	-2.04 (0.06)***	-37.01	-2.15 - -1.9	0.21 (0.07)**	2.97	0.07 - 0.34
Slope	-0.02 (0.01)*	-2.13	-0.03 - -0.001	-0.01 (0.01)	-0.90	-0.02 - 0.01	-0.03 (0.01)**	-2.71	-0.05 - -0.01
US vs UK	-0.01 (0.01)	-1.16	-0.02 - 0.01	-0.003 (0.01)	-0.56	-0.01 - 0.01	-0.02 (0.01)*	-2.51	-0.03 - -0.004
Remain vs Leave	-0.01 (0.01)	-1.37	-0.03 - 0.004	0.004 (0.01)	0.50	-0.01 - 0.02	-0.002 (0.01)	-0.16	-0.02 - 0.02
Correlation									
Intercept ~~ Slope	-0.14 (0.10)	-1.50	-0.33 - 0.04	-0.17 - 0.13	-1.28	-0.43 - 0.	-.04 (0.13)	0.76	-0.29 - 0.22
Model Fit Indices									
Comparative Fit Index (CFI)	–	0.998		–	0.999		–	0.982	
Robust Tucker-Lewis Index (TLI)	–	0.998		–	0.999		–	0.978	
Root Mean Square Error of Approximation (RMSEA)	–	0.023		–	0.017		–	0.044	

* *p* < .05. ** p < .01. *** p < .001.

Table A9

The number of Leave and Remain participants who were aged above 60 at each survey

Group	Survey 1	Survey 2	Survey 3	Survey 4
Leave	17	24	23	19
Remain	32	34	33	31

4. Chapter 4: The Positivity Effect: Exploring age-related differences in the neural time course of emotional processing and long-term emotional memory

4.1 Abstract

The ‘positivity effect’ in which older adults demonstrate a preference for positive over negative information is believed to depend on cognitive control abilities. The current study investigates the neural mechanisms responsible for this age-related shift in 25 younger adults aged between 18 and 26 and 37 older adults aged between 50 and 83 and specifically examines the areas responsible for emotional processing and cognitive control such as the amygdala, ventromedial prefrontal cortex (vmPFC) and pregenual anterior cingulate cortex (pgACC). Both general activation levels and the neural time courses of the amygdala, vmPFC and pgACC of younger and older adults were examined separately in response to viewing negative, positive and neutral stimuli. Consistent with our hypothesis, older adults demonstrated a positivity effect in behavioural memory measures. Additionally compared to younger adults, older adults showed a reduction in general levels of amygdala activation to negative stimuli and increased general levels of pgACC activity to positive over negative stimuli. Meanwhile, when examining the time course of activation, there were no group differences in amygdala or vmPFC activity to negative or positive images over time. However, older adults showed increased pgACC activity to emotional stimuli relative to younger adults. Our results suggest that older adults show a selective reduction in general amygdala activity to negative stimuli but that the amygdala responds similarly to that of younger adults over time. However, older adults seem to rely more heavily on the recruitment of prefrontal areas during the emotional processing of emotional stimuli over time which could reflect an increase in implementing cognitive control abilities that facilitate later memory.

4.2. Introduction

Whereas younger adults typically attend to more negative information (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Roalf, Pruis, Stevens, & Janowsky, 2011) older adults exhibit a preference for positive information in both attention (Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Kappes, Streubel, Droste, & Folta-Schoofs, 2017; Sasse, Gamer, Büchel, & Brassen, 2014) and memory (Charles, Mather, & Carstensen, 2003; Joubert, Davidson, & Chainay, 2018; Kan, Garrison, Drummey, Emmert, & Rogers, 2018; Kennedy, Mather, & Carstensen, 2004). Compared to younger adults, older adults preferentially look at positive faces over negative ones (Mather & Carstensen, 2003) and recall more positive autobiographical memories (Tomaszczyk & Fernandes, 2013). This age-related trend is known as the *positivity effect*, and was confirmed in a meta-analysis to be a reliable small-to medium effect that is stronger when the processing of stimuli is unconstrained (Reed, Chan, & Mikels, 2014).

Some researchers argue that this pattern stems from the neural decline associated with aging, particularly the neural degeneration of the amygdala. The *Aging-brain model* (Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011) theorizes that age-related neural decline results in attenuated amygdala activation, specifically to negative but not positive stimuli (Berntson, Bechara, Damasio, Tranel, & Cacioppo, 2007); a pattern that was evidenced in patients with amygdala lesions who provided lower arousal ratings specifically to negative images but not positive ones (Adolphs & Tranel, 2004). As such, the theory suggests that older adults would be less likely to benefit from the emotional enhancement of negative stimuli in subsequent memory. However, a reduction in in arousal ratings among older adults specifically for negative images is not always found (e.g. Gavazzeni, Wiens, & Fischer, 2008; Grühn & Scheibe, 2008b) indicating that older adults still maintain the ability to detect arousing stimuli. More importantly however, this selective pattern of impairment specifically to negative stimuli does not necessarily extend to other tasks that rely upon the amygdala. For example, fear acquisition has been shown to be preserved in older adults (LaBar, Cook, Torpey, & Welsh-Bohmer, 2004; Sakaki, Raw, Findlay, & Thottam, 2019). In other words, older adults can acquire fear responses to cues that predict an aversive outcome just as younger adults can (Sakaki et al., 2019) suggesting that they maintain the ability to process negative arousing stimuli. Likewise, older adults show greater amygdala activity for later remembered negative images compared to later remembered neutral images (St. Jacques, Dolcos, & Cabeza, 2009) suggesting they equally benefit from emotional memory enhancement like younger adults do. Therefore, the aging-brain model does not provide a comprehensive explanation as to why the amygdala in older adults shows a selectively weaker response to negative over positive stimuli.

An alternative theory, that accounts for the selective reduction in amygdala activity to negative over positive stimuli in older adults, is the Socioemotional Selectivity Theory (SST: Carstensen, Isaacowitz, & Charles, 1999; Carstensen & Lang, 1996). Unlike the aging-brain model, this theory postulates that with age, and consequently the increasing awareness of the limited time we have left in our lives (Barber, Opitz, Martins, Sakaki, & Mather, 2016; Neta, Tong, & Henley, 2018; Scheibe & Carstensen, 2010), we experience a motivational shift in favour of emotional stability and positive experiences over increasing knowledge or wealth (Carstensen et al., 1999). According to the SST then, the positivity effect arises because older adults are implementing goal-directed selective attention that allows them to ignore negative information (Mather & Carstensen, 2003) and/or attend to positive information (Isaacowitz et al., 2006). As such, when presented with negative stimuli, older adults are thought to engage in emotion regulation strategies that attenuate amygdala activation (Mather et al., 2004).

Yet, such goal-directed behaviour such as maintaining goal-states, pursuing goals and regulating emotion, even for younger adults, requires a certain level of cognitive control (Opitz, Lee, Gross, & Urry, 2014; Paxton, Barch, Racine, & Braver, 2008). At the same time however, increasing age is associated with a decline in cognitive performance (Nyberg, Lövdén, Riklund, Lindenberger, & Bäckman, 2012; Salthouse, 2011). For example, age-related deficits are seen in cognitive control processes such as selective attention (Samanez-Larkin, Robertson, Mikels, Carstensen, & Gotlib, 2009), task-switching and inhibitory control (Darowski, Helder, Zacks, Hasher, & Hambrick, 2008) at the same time that age-related changes in the brain such as decreasing grey matter volume (Fjell & Walhovd, 2010; Manard, Bahri, Salmon, & Collette, 2016) and decreasing connectivity (Grieve, Williams, Paul, Clark, & Gordon, 2007) are seen in the frontal lobes.

Despite these age-related declines however, increasing age does not always impair emotional control and older adults are still able to implement goal-directed behaviour (Mather & Knight, 2005). The cognitive control model proposed by Mather and Knight (2005), which extends on the SST, stipulates that aged individuals with reduced cognitive control abilities would struggle to achieve goal-directed behaviour and consequently would be less likely to show the positivity effect. They tested this hypothesis by testing younger and older adults' recall in a full-attention condition versus a distraction condition and found that the positivity effect diminished for older adults in the condition where their cognitive resources were split. They concluded that older adults with poorer cognitive control abilities are less likely to show the positivity effect. Since then, further evidence has emerged to support this cognitive control theory (Mather & Knight, 2005); that the positivity effect is dependent upon cognitive resources (Isaacowitz, Toner, & Neupert, 2009; Joubert et al., 2018; M. Knight et al., 2007; Sakaki et al., 2019) and when older adults' access to cognitive resources are reduced, they show more similar patterns to that typically seen in younger adults (Joubert et al., 2018).

As previously mentioned, amygdala activation is commonly reduced in response to negative stimuli (Erk, Walter, & Abler, 2008; Mather et al., 2004; St. Jacques et al., 2009) but not in response positive stimuli (Leclerc & Kensinger, 2011) among older adults. Whereas the aging brain model would predict this pattern to be associated with age-related structural decline, the SST and cognitive control theory considers that older adults may spontaneously engage in emotion regulation strategies when encountering positive and negative stimuli (Mather, 2012; Nashiro, Sakaki, & Mather, 2012) and in doing so, recruit prefrontal cortex (PFC) areas responsible for emotion regulation such as the medial PFC (mPFC; Urry & Gross, 2010; Urry et al., 2006) and the ventromedial PFC (vmPFC; Leclerc & Kensinger, 2008). This hypothesis is supported by findings of increased activity within the PFC; an area known to exert control of emotion (Ochsner & Gross, 2005) and regulate affect (Phan, Wager, Taylor, & Liberzon, 2002), when viewing negative images (Leclerc & Kensinger, 2008; Roalf et al., 2011; Williams et al., 2006). Moreover, there is evidence of an inverse coupling between the vmPFC and the amygdala during emotion regulation strategies such as reappraisal (Johnstone, Van Reekum, Urry, Kalin, & Davidson, 2007; Urry et al., 2006) suggesting that an increase in vmPFC activity may facilitate the down-regulation of negative affect by reducing amygdala activation. Similarly, the affective division of the anterior cingulate cortex (ACC) including the pregenual ACC has also been implicated in the evaluation of emotional salience (Phan et al., 2002) and is considered to play a role in emotion regulation via the modulation of the amygdala (Ochsner, Bunge, Gross, & Gabrieli, 2002). It is also considered to be important in tasks that require cognitive control when there is emotional stimuli involved (Mohanty et al., 2007). As such, the aforementioned evidence has led researchers to speculate that the positivity effect may arise due to older adults engaging prefrontal regions responsible for implementing goal-directed behaviour such as emotion regulation that allows them to ignore negative information and attend to positive information.

Indeed, several studies have evidenced age-related differences in the recruitment of the amygdala and PFC during emotional processing which supports this proposal. For example, compared to younger adults, older adults have been found to exhibit greater medial PFC and

ACC activation to negative compared to neutral stimuli (Gunning-Dixon et al., 2003; Roalf et al., 2011; Williams et al., 2006). Moreover, when asked more specifically to down-regulate their emotions while viewing negative images, older adults exhibited greater vmPFC activity and a reduction in the recruitment of the amygdala (Urry et al., 2006). Therefore, in line with the SST and the cognitive control model, it is possible that older adults implement top-down goal processes when experiencing negative affect. As such, the positivity effect could be a consequence of the down-regulation of amygdala activity via frontal cortical signals (Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003). In addition, there is also evidence of increased connectivity between the amygdala and the vmPFC during the encoding of positive stimuli among older adults (Addis, Leclerc, Muscatell, & Kensinger, 2010); a pattern which is also associated with more positive memories (Sakaki, Nga, & Mather, 2013). Collectively then, the evidence would suggest that increased aging is associated with sustained prefrontal activity in response to emotional stimuli and that vmPFC and pgACC seem to be critical in the processing of emotional stimuli and in the down regulation of negative affect, especially among older adults. Therefore, the positivity effect may manifest in neural activation as an increase in prefrontal activity and a selective reduction in amygdala activity specific to negative stimuli (Leclerc & Kensinger, 2008).

However, if the positivity effect is dependent upon cognitive control abilities, it may occur gradually over time. Indeed, there is some evidence that demonstrates the role of cognitive control in the positivity effect and the time course of emotional processing in younger and older adults. For example when encountering emotional stimuli, older adults show similar initial patterns of behaviour to younger adults in several automatic processes such as threat detection (Lee & Knight, 2009; Mather & Knight, 2006) but differ from younger adults after a delay (Isaacowitz, Allard, Murphy, & Schlangel, 2009). Therefore, it appears that older adults are able to overcome automatically processing negative information (e.g. Kisley, Wood, & Burrows, 2007) by implementing top-down mechanisms that allow them to prioritise the processing of positive over negative information. If this is the case, then the positivity effect should emerge over time and not straight away. In other words, older adults should initially show similar responses to younger adults (i.e. automatic processing of negative information) before exhibiting a shift towards preferentially processing positive information. Isaacowitz and colleagues (2009) found evidence of this delayed shift in an eye-tracking study. Since older adults have also been shown to demonstrate the positivity effect in gaze preferences by directing their gaze toward happy and away from angry or sad faces (Isaacowitz et al., 2006), they examined whether older adults' preferential fixations toward positive and away from negative stimuli emerged initially (indicative of automatic processing), or over time. In line with the cognitive control theory (Mather & Knight, 2005), they found that older adults' preference for positive images emerged after a 500ms delay and not immediately after stimulus presentation, supporting the idea that the preferential processing of positive images was not automatic but rather a consequence of recruiting cognitive resources to implement goal-directed attention to positive information. Therefore, the behavioural evidence appears to suggest that the differences in the processing of emotional stimuli between younger and older adults does in fact emerge over time (Isaacowitz, Allard, et al., 2009).

However, there are fewer MRI studies that have examined the time course of brain activation in relation to the positivity effect. Among the studies that have, there is tentative evidence to suggest that the time course of neural activation when processing emotional stimuli is different between younger and older adults. For example in one study, unpleasant emotional video clips were presented to younger and older adults and participants were instructed to adopt a method of emotional regulation or simply passively view the images (Allard & Kensinger, 2014). They found that immediate and delayed activity within the right ventrolateral PFC was different between younger and older adults during reappraisal-related activity; younger adults showed greater immediate activity whereas older adults showed greater activity at the emotional peak of the film clips (in other words, after a delay). Although there is some ambiguity as to what these neural differences may reflect; with one interpretation being that older adults are exhibiting more efficiency by intentionally waiting for the appropriate moment to deploy their emotion regulation strategy, it could also be that compared to younger adults, older adults require a greater length of time to recruit cognitive resources to cope with emotional information. The latter interpretation however, fits with behavioural evidence which suggests that the positivity effect may in fact emerge over time. If this is the case, it may reflect the greater amount of time needed for older adults to implement goal-directed behaviour which would allow them to concentrate more on positive information and ignore negative information over time.

In a separate study, which examined the age differences in the maintenance and habituation of brain activity, a different pattern was found. Roalf and colleagues (2011) presented younger and older adults with different valenced image blocks containing 40 images and modelled early (the first 20 images) and late (the last 20 images) activation. They found that the number of active voxels within the dorsolateral PFC in older adults was not maintained in the late activation stage to negative images but was to positive and neutral images. Interestingly, they also found reduced amygdala activity among older adults, leading them to speculate that their results reflected a shifting of attention to positive stimuli within older adults. In other words, they found possible support for the cognitive control model. However, it is worth highlighting some of the study's limitations. Firstly, in their behavioural results for the memory test, older participants did not demonstrate a preference for positive over negative images and showed a similar pattern to that of younger adults in which they remembered more negative than positive or neutral images. Therefore, if it were the case that older adults were in fact shifting their attention to positive images, then the authors may have expected to find increased memory performance for positive images, yet they did not. Secondly, in terms of their fMRI analysis, they modelled the early and late phase without using a jittered interval between the two meaning that the activation in the early and late phase is likely to be correlated. Finally, the arousal ratings obtained from participants indicated that negative images were considered to be more arousing than both positive and neutral stimuli. Therefore any valence-specific effects, particularly those concerning negative emotion, could be confounded by a difference in arousal levels and not specifically due to valence.

Therefore, while there is some research to suggest that there may be differences in the time course of amygdala and prefrontal activity during emotional processing between younger and older adults, the current evidence is mixed and warrants further exploration. The current study therefore aimed to directly test whether there are any age-related differences in the temporal changes in the amygdala, the vmPFC and the pgACC in response to the processing of emotional and neutral stimuli. We hypothesized that we would replicate the age-related positivity effect documented in the literature (see Reed et al., 2014 for a review): while older adult's memory would be poorer overall in comparison to younger adults, they would demonstrate the positivity effect by remembering more positive than negative images relative to younger adults. Importantly, we do not expect this effect to arise due to age-related differences in arousal ratings for negative images as the Aging Brain Model has previously proposed. Secondly, in line with the SST and the cognitive control theory, we predicted that average levels of amygdala activity would be selectively reduced among older adults to negative information and that average levels of vmPFC and pgACC activation would be greater among older adults viewing emotional information as has been previously documented (Gunning-Dixon et al., 2003; Leclerc & Kensinger, 2008; Urry et al., 2006).

Thirdly, if older adults' positivity effects are the result of goal-directed attention that allows them to avoid negative information and attend to positive information, then we expected there to be differences in the neural time courses of the amygdala, vmPFC and pgACC. More specifically, we hypothesized that older adults, over time, would show a gradual reduction in amygdala activation to negative images but would also show increased vmPFC and pgACC activation when encountering emotional stimuli compared to younger adults.

4.3 Methods

4.3.1 Design

The experiment was split into two sessions with the second session occurring one week after the first session. We used a 2 x 3 design with age (younger vs. older adults) as a between-subjects factor and image valence (valence: positive, negative and neutral) as a within-subjects factor to assess participants' memory and valence ratings for the stimuli to see if (1) we could replicate the positivity effect in long-term memory and (2) to see if younger and older adults rated emotional stimuli similarly.

For the one week interval between the two laboratory-based experimental sessions, we also used an experience sampling method using an iPod touch with experience sampling-software installed (iDialog Pad, see Kubiak & Krog, 2012) to investigate: (1) whether older adults exhibited better mood in self-reported measures of emotional well-being and (2) whether emotional well-being can predict the positivity effect in memory (the results for this part will be discussed in the next chapter).

4.3.2 Participants

Participants included 43 older adults (22 females; age range: 50-87; *M*age = 67.26, SD = 9.76) and 26 younger adults (19 females; age range: 18-26; *M*age = 19.81, SD = 2.02). Older adults were recruited from the Ageing Research Panel at the University of Reading and the local area around Reading, Berkshire, UK, ensuring a wide age range was covered. Younger adults were undergraduate and graduate students at the University of Reading. Potential participants were excluded if they reported any contraindications to MRI scanning such as metal implants and pacemakers etc. or if they had any known cognitive impairments. Participants were not explicitly screened for colour blindness but were asked by the researcher for the purpose of the Stroop task. We recruited as many older adults as possible within the study time line (between September, 2017 and April, 2019).

One younger participant withdrew from the study and one older adult was excluded from the analysis because they did not fully complete the first session (see Appendix 1; Table A1 for demographic information for all participants). A further five older adults who did not meet the cut-off score of 26 on the Mini Mental State Examination (MMSE: Folstein, Folstein, & McHugh, 1975) were excluded from all analyses (see Appendix 3 for supplementary tables and figures for analyses including these participants) so that we could be more confident that our results were not the consequence of age-related memory impairments associated with dementia. The remaining participants included in the analysis comprised of 37 older adults (18 females; age range: 50-83, *M*age = 66.03, SD = 8.87; MMSE range 26-30, *M*= 28.27, SD = 1.39) and 25 younger adults (18 females; age range: 18-26; *M*age = 19.6, SD = 1.76). Ethical approval for the study was obtained from the University of Reading Ethics Committee and each participant provided their consent and received either £7/hour or course credits.

For MRI results, an additional six participants were excluded due to excessive motion i.e. if their maximum framewise displacement was greater than 3mm (4 older adults and 2 younger adults). The final participants included 33 older adults (17 females; age range: 50-83, *M*age = 65.52, SD = 8.90; MMSE range 26-30, *M*= 28.24, SD = 1.41) and 23 younger adults (16 females; age range: 18-26, *M*age = 19.61, SD = 1.78).

Post-hoc sensitivity analysis using GPower (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that our final sample sizes for our behavioural and MRI data would provide 80% power to detect an interaction between valence and age group with a small effect size of f = .16 for our behavioural data and f = .19 for our MRI data.

4.3.3 Apparatus

Physiological measures were obtained however, they are beyond the scope of this study and so are not reported here. We used a PowerLab 26T device with an amplifier (AD Instrument Ltd, Oxford, UK) to record skin conductance responses (SCR) and finger pulse rate whilst they were in the MRI scanner. Two finger electrodes were attached to the participants' middle and ring finger on their left hand to record their physiological responses and a third electrode on their index finger to record their finger pulse. Labchart (AD Instrument Ltd, Oxford, UK) was used to record participant's physiological responses.

To administer the emotional diary, an iPod touch (Generation: 6, Apple Inc.) was provided with experience sampling-software installed (iDialog Pad, see Kubiak & Krog, 2012).

Table 4.1

Demographic measures and results in cognitive and self-reported questionnaires from Session 1 (S1) and 2 (S2).

	Behavioural Analysis		MRI analysis	
	Young n = 25	*Old* n = 37	*Young* n = 23	*Old* n = 33
Mean Age (in years)	19.6 (1.7)	66.03 (8.87)	19.61 (1.78)	65.52 (8.90)
Age range (in years)	18-26	50-83	18-26	50-83
Sex (females/males)	18/7	18 / 19	16/7	17 / 16
Education (in years)	13.72 (1.72)	14.68 (3.15)	13.65 (1.72)	14.73 (2.88)
MMSE	-	28.27 (1.39)	-	28.24 (1.41)
Psychological well-being scale	13.97 (3.33)	14.81 (3.05)	13.85 (3.45)	14.76 (3.10)
Positive Affect (S1)	28.16 (7.24)	35.26 (8.45)	28.65 (7.35)	35.81 (8.24)
Negative Affect (S1)	13.56 (5.12)	11.23 (1.78)	12.74 (2.58)	11.00 (1.67)

CES-D (S1)	15.60 (11.72)	7.17 (6.76)	14.82 (10.96)	6.47 (5.96)
Positive Affect (S2)	25.72 (7.51)	35.92 (7.21)	25.70 (7.80)	36.82 (6.52)
Negative Affect (S2)	12.76 (3.22)	11.24 (2.94)	12.87 (3.33)	10.67 (1.05)
CES-D (S2)	15.64 (9.12)	7.38 (6.90)	15.26 (8.93)	6.64 (5.50)

4.3.4 Materials

A total of 360 images (120 positive, 120 negative and 120 neutral) were obtained from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997) the Open Affective Standardized Image Set (Kurdi, Lozano, & Banaji, 2017) and the Internet to be used as the stimuli. To select stimuli that induce similar affective reactions across younger and older adults, a pilot study was conducted. We did not have a pre-determined sample size but instead aimed to collect as much data as possible. Our final sample size included 29 older adults (16 females; *M*age = 63.62 years, SD=2.59) and 33 younger adults (16 females; *M*age = 27.19 years, SD = 4.39) who were asked to participate in an online study in which they were asked to rate each image on arousal using a 9-point scale ranging from 1 (calm) to 9 (excited) and valence using a 9-point scale ranging from 1 (negative) to 9 (positive). As we wanted to ensure the reliability of participants' responses, the data of 12 older adults and 18 younger adults was removed since these participants provided the same arousal ratings on consecutive trials for more than 33% of the trials. The remaining participants included 18 older adults (8 females; *M*age = 63.39 years, SD = 2.67) and 11 younger adults (4 females; *M*age = 26.73, SD = 4.94). Despite having to exclude these participants, our sample size is still larger than other pilot studies examining ratings of IAPS images (Grühn & Scheibe, 2008a). The mean valence and arousal levels for each image were used to determine which images were rated more similarly between younger and older adults in terms of arousal and valence measures. From the images rated in the pilot study, those that had the lowest difference scores for arousal and valence were selected for the experimental lists for the main study. Overall, images that were included in the experimental lists had a difference score of less than 1.77 for valence and 2.32 for arousal between younger and older adults. Negative images were given the lowest rating (*M*old = 2.09, *SD* = .58; *M*young = 2.14, *SD* = .44), followed by neutral images (*M*old = 4.93, *SD* = .36; *M*young = 4.89, *SD* = .27) and then positive images which were given the highest rating (*M*old = 6.63, *SD* = .27; *M*young = 6.63, *SD* = .25). As for arousal, both negative (*M*old = 4.71, *SD* = .30; *M*young = 3.57, *SD* = .43) and positive images (*M*old = 4.90, *SD* = .24; *M*young = 4.05, *SD* = .30) were rated as more arousing than neutral ones (*M*old = 3.34, *SD* = .32; *M*young = 2.58, *SD* = .32).

Of the total 360 images, 270 images (90 positive; 90 negative and 90 neutral) were shown to participants during the encoding phase (Session 1) and a further 90 foil images were presented in Session 2 during the memory test and rating task. A total of eight experimental image lists containing 270 ‘old’ images and 90 foils were created so that the assignment of ‘old’ and foil images was counterbalanced across participants. For each list, the images were matched on the number of indoor images, sociality (i.e. whether the image contained humans), and valence and arousal ratings.

3.3.4.1 Lab-based questionnaires

In order to assess the current and recent emotional state of each participant, the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988), the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977) and a psychological well-being scale (PWB Scale; Ryff & Keyes, 1995) were administered. Participants also completed a questionnaire on life satisfaction (Diener, Emmons, Larsem, & Griffin, 1985) and a demographic questionnaire (Appendix C).

4.3.5 Behavioural Procedures

4.3.5.1 Session 1

The first experimental session involved obtaining consent and then completing some mood and life questionnaires (e.g., CES-D, PANAS, PWB Scale, Life Satisfaction) and a demographic questionnaire before practicing the main experimental task (see Figure 4.1. for experimental procedure overview). In the practice task, participants were instructed that they would be presented with many positive, negative and neutral images whilst they were in the scanner but irrespective of the valence of the image, they just needed to indicate if the image depicted an outdoor or an indoor scene. After the practice, participants were allowed to ask questions about the main task and were then invited to take part in the emotional diary study. Once again they were informed about the procedures of the study and for those who agreed to take part, their consent was obtained. They were then given instructions on how to use the iPod to answer the survey questions and were given a guide on how to use it.

Participants were then taken to the MRI unit, and were fully screened in accordance with the initial and secondary screening procedures set by the Centre for Integrative Neuroscience and Neurodynamics (CINN) at the University of Reading. Before entering the MRI scanner, participants who wore or required glasses were given MRI-safe goggles to adjust their vision whilst inside the scanner. Finger electrodes to measure skin conductance and heart rate were attached to their non-dominant hand. Participants were then reminded of the experimental instructions and were able to complete another practice session while a structural scan (T1) was carried out. After the structural scan, participants began the main experimental task which was divided into three separate runs. Each run lasted approximately 9 minutes and included 9 valenced blocks (3 x negative, 3 x neutral and 3 x positive; see Figure 4.2 for example run). The block presentations were separated by a jittered inter-block interval during which a fixation cross was presented for a minimum of 16 sec up to a maximum of 23 sec. Within each valenced block, there were 10 images and each image was presented for 3 sec followed by a 500ms blank interval. Across all three runs, participants viewed a total of 90 negative, 90 positive and 90 neutral images. The order of the blocks was pseudorandom and different across participants. The images within each block were presented in the same order and it was ensured that two consecutive blocks would not have the same valence category. For the task, participants were simply instructed to indicate whether each image depicted an 'indoor' or 'outdoor' scene by pressing one of two buttons. After scanning, participants were asked to fill out a post-task questionnaire and were then given an iPod to take home.

4.3.5.2 Session 2

The second session was arranged for one week later. They returned to the laboratory and were asked to fill in some mood and life questionnaires (CES-D, PANAS, and the interest and deprivation factors of epistemic curiosity: Litman, 2008) and were also given a questionnaire relating to their experience of using the iPod touch. Once the questionnaires were completed, a self-paced memory test was administered. During this test, participants were presented with the 270 images that they saw in the scanner and an additional 90 foil images. Participants were asked to indicate whether they had seen the image or not during the main MRI task.

Following this, participants then viewed the same images but this time were asked to provide a valence rating for each image using a scale from 1-9; 1 indicating very negative to 9 indicating very positive.

4.3.5.3 Tasks assessing cognitive capabilities

Upon completion of the memory test, participants' cognitive capability was assessed. Here, a cognitive assessment battery comprised of several tasks taken from the Wechsler Adult Intelligence Scale-Revised (WAIS-R) such as trail making, block design, and verbal fluency in addition to the Stroop task, together with the MMSE was administered.

Collectively, these tests assess working and episodic memory, executive functioning and language proficiency (see Appendix D). These measures were collected as part of the ageing panel battery and are not relevant to main study and are therefore not reported (with the exception of the MMSE scores).

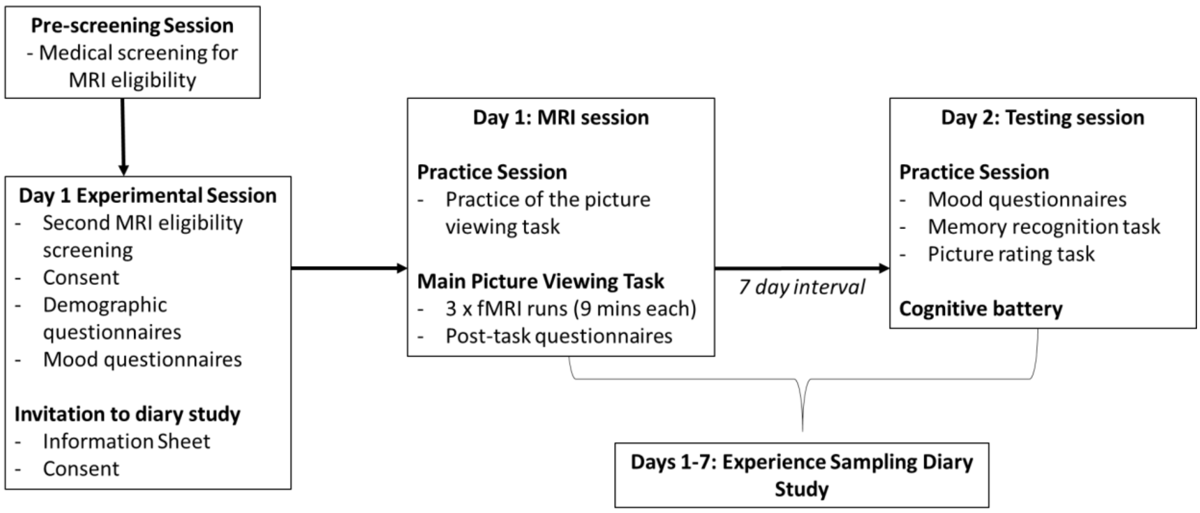

Figure 4.1. Flow chart of study procedure; see main text for details

4.3.6 Behavioural Data Analysis

Cognitive impairment. The Mini Mental State Examination (MMSE; Folstein et al., 1975) is a cognitive impairment screening tool that comprises of 30 items that measure different cognitive functions such as orientation, recall, registration, attention and calculation, and language. The maximum score is 30 with scores of less than 26 indicating a possible cognitive impairment.

Memory test. Corrected recognition scores for each participant were calculated separately for each valence by subtracting the number false alarm rates from the number of correctly identified old images. In addition, a memory positivity score was obtained by subtracting the corrected recognition scores (hit minus false alarm rate) of negative images from the corrected recognition scores of positive images in order to examine whether there was a greater benefit for positive versus negative images in memory for older adults compared to younger ones.

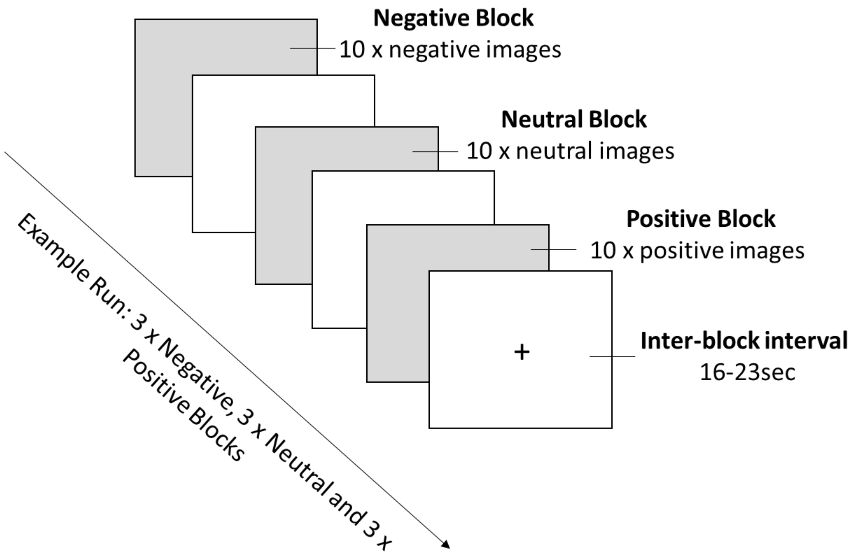

Figure 4.2. Example run. Each run contained 9 blocks; 3 of each valence that were separated by a jittered inter-block interval of 16-23sec. Within each block, 10 valenced images were presented for 3sec followed by a 500ms blank interval.

4.3.7 FMRI data acquisition and preprocessing

Brain images were collected using a 3.0-T Siemens Prisma Trio scanner with a 32-channel matrix head coil at the Centre for Integrative Neuroscience and Neurodynamics, University of Reading. High-resolution (T1-MPRAGE) structural images were acquired before the functional scans (repetition time or TR = 2400ms; echo time or TE = 2.41ms; flip angle or FA = 8°; 224 mm field of view; slice thickness = .70mm). Functional images were acquired using a T2*-weighted gradient-echo, echo planar imaging (EPI) pulse sequence with 2mm thickness with 2.2 mm gap and a TR of 996ms; TE = 33ms; flip angle = 90°; 82mm field of view. Two reversed phase-encoded blips, producing a pair of images with distortions in the opposite direction were also acquired (Andersson, Skare, & Ashburner, 2003).

Data preprocessing were performed using FMRIB's Software Library (FSL; www.fmrib.ox.ac.uk/fsl; Smith et al., 2004). Brains were extracted from the structural images using FSL Brain Extraction Tool (BET). Field correction was conducted using the opposite phase encoded images using FSL's topup tool (Andersson et al., 2003). MCFLIRT was used for distortion, and motion correction. Gaussian smoothing and a high-pass temporal filter of 109 sec was applied for our general activation analysis whereas a high-pass temporal filter of 490 sec was used for the time course analysis. Registration was performed using FLIRT with each functional image being registered to the participant's high-resolution brain extracted image and to a standard Montreal Neurological Institute (MNI) 2mm brain. To identify artefacts, MELODIC Independent Component Analysis (ICA; Beckmann & Smith, 2005) was used.

4.3.7.1 General activation analysis

For the general activation analysis, noise components identified by MELODIC were hand-classified by coders before being removed using suggested criteria by Griffanti et al. (2017) and (Kelly et al., 2010). For each run, General Linear Models (GLMs) were carried out which included three EVs: positive, negative and neutral. The analysis modelled the following 3 contrasts: 1) positive > negative, 2) positive > neutral and 3) negative > neutral. Six motion estimate covariates and motion outliers (defined as outliers based on the 75^{th} percentile + 1.5 times the Interquartile range) that were extracted using FSL's motion outliers tool (FSL v.6.0, FMRIB's Software Library, https://fsl.fmrib.ox.ac.uk/fsl/; Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012; Smith et al., 2004) were also included in the model to remove any brain activity or movement that was unrelated to the task. A second fixed-effect GLM was then performed to concatenate all three runs for each participant. The results from this were then used in the subsequent group analyses.

Regions of Interest. We defined a priori regions of interest (ROIs), including the amygdala, the ventromedial prefrontal cortex (vmPFC) and the pregenual anterior cingulate cortex (pgACC; see Figure 4.3). Amygdala volumes for each participant were obtained using FSL's FIRST segmentation tool (Patenaude, Smith, Kennedy, & Jenkinson, 2011) on each individuals' T1 image. This method uses a Bayesian probabilistic model that uses the shape and intensity from 336 manually segmented and labelled T1 images to infer boundary areas of structures. The segmented subcortical structures were visually inspected to ensure that the segmentation was appropriate. In addition, we defined a ROI based on an anatomically defined mask of the vmPFC and the pgACC obtained from de la Vega et al.'s (2016) meta-analysis that examined the role of the medial frontal cortex in psychological processes such as cognitive control and affect.

For the general activation analysis, we used FSL's Featquery to extract β coefficients for the mean parameter estimate values each of these ROIs, for each subject using the positive>neutral, negative>neutral and positive>negative contrasts.

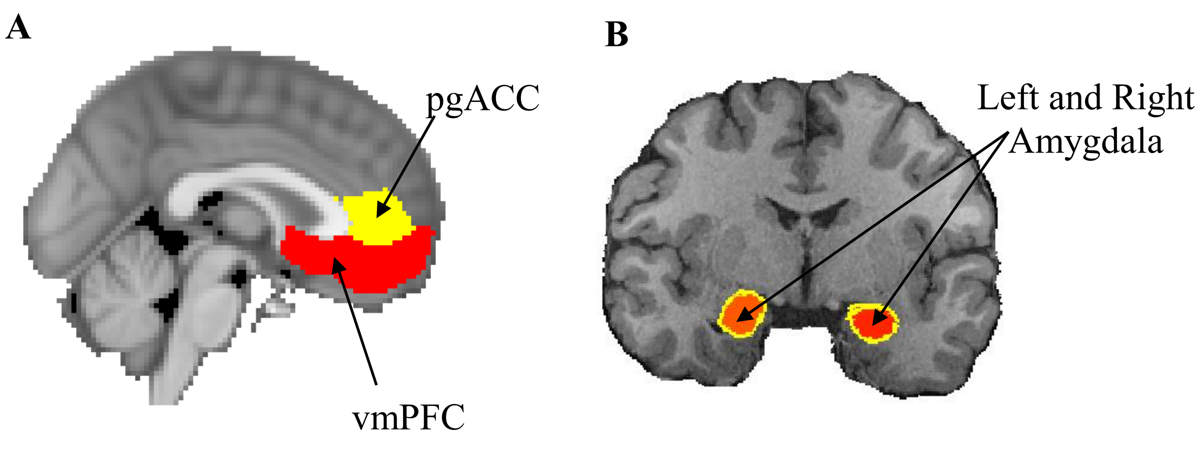

Figure 4.3 Regions of interest for A) the pgACC and vmPFC and B) the left and right amygdala.

4.3.7.2 Time course analysis

For this analysis, a high-pass temporal filter of 490 sec was used. For the time course analysis, FSL's FIX ICA-based noise correction (Griffanti et al., 2014) was used to classify ICA components. Since our study contained younger and older adults, we trained FIX using our own study data rather than using FSL's trained-weights files. In order to do this, we randomly selected 10 younger and 10 older adults (including data from all three runs) and hand-classified the noise components into "good" versus "bad". This *training data* was then used to run FIX on the remainder of our data.

In order to examine the time course of activation, we modelled each valence block separately across the three runs and extracted 9 amygdala, vmPFC and pgACC response estimators, per subject using similar methods to Plichta et al. (2014):

$$Y= bX+a$$

The mean BOLD response, "Y", is predicted by the log transformed block number "X". In other words, blocks 1-9 were transformed using natural logarithm to 0, 0.69, 1.10, 1.39, 1.61, 1.79, 1.95, 2.08 and 2.20. The intercept within the regression model is the estimate of the initial reactivity and the regression coefficient *b* is an estimate of the rate of change. Previous research has shown that *b* is dependent on *a*, therefore, following Plichta et al.'s method, we calculated absolute habituation (Montagu, 1963; Plichta et al., 2014) using $b' = b - c(a - \bar{a})$. Here, c is the slope of *b* on a and ā is the mean of a. The absolute habituation index is b' which is a measure that is independent of initial amplitudes. A negative value of b' indicates habituation whereas a positive value indicates an increase in activation over time and a 0 value represents no change

Using the same ROIs mentioned previously under 'general activation analysis', we tested whether the left and right amygdala, vmPFC and ACC time courses were differentially modulated by age (young vs. old) and by valence category (positive vs. negative vs. neutral). We obtained a difference score in the slope of the positive vs. neutral condition and a difference score in the slope of the negative vs. neutral condition. Then we computed a mixed effects model with the activation time course as the dependent variable and group (old vs. young) and valence (positive vs. neutral and negative vs. neutral) as fixed effects.

For all MRI analyses, we report corrected *p* values i.e. the *p* values after applying a false discovery rate correction based on the number of ROIs ($n = 4$).

4.4 Behavioural Results

4.4.1 Mood

When examining the PANAS scores on Day 1[8], older adults reported significantly higher ratings of positive affect compared to younger adults (M_{Old} =35.26, SD = 8.45; M_{Young} = 28.16, SD = 7.24), t (60) = 3.40, p = .001. Furthermore, older adults reported significantly lower negative affect than younger adults (M_{Old} =11.23, SD = 1.78 M_{Young} = 13.56, SD = 5.12), t (60) = -2.50, p = .02. Older adults reported lower levels of depressive symptoms compared to younger adults (M_{Old} = 7.17, SD = 6.76; M_{Young} = 15.60, SD = 11.72), t (60) = -3.56, p < .001.

On Day 2, older adults reported significantly higher ratings of positive affect compared to younger adults (M_{Old} = 35.92, SD = 7.21; M_{Young} = 25.72, SD = 7.51), t (60) = 5.37, p < .001 and significantly lower levels of depressive symptoms compared to younger adults (M_{Old} = 7.38, SD = 6.90; M_{Young} = 15.64, SD = 9.12), t (60) = -4.06, p < .001. However, there was no significant difference in negative affect between younger and older adults (M_{Old} =11.24, SD = 2.94; M_{Young} = 12.76, SD = 3.22), t (60) = -1.92, p = .06.

4.4.2 Memory

Effects of age and valence on corrected recognition scores. A 3 (valence: negative vs. neutral vs. positive) x 2 (group: young vs. old) ANOVA on the corrected recognition

[8] The data of two older adults were missing for this questionnaire and are therefore not included in this analysis.

scores for trials in the memory test showed a main effect of group, $F(1, 60) = 13.56$, $p < .001$, $\eta^2G = .80$; More specifically, younger adults' memory performance was significantly higher compared to that of older adults ($M_{young} = .33$, SD = .18; $M_{old} = .22$, SD = .14; see Table 4.2; Figure 4.4). This indicates an age-related difference in memory corrected recognition scores, as shown in previous studies. In addition, we found a significant main effect of valence, $F(2,120) = 75.73$, $p < .001$, $\eta^2G = 0.27$, which was further qualified by a significant interaction between group and valence, $F(2, 120) = 9.92$, $p < .001$, $\eta^2G = .05$.

Subsequent analysis conducted separately for each valence condition revealed that younger adults recalled a greater proportion of positive ($M_{young} = .26$, SD = .12; $M_{old} = .18$, SD = .11; see Table 4.2), $F(1, 60) = 8.17$, $p = .006$, η2G = .12, and negative ($M_{young} = .48$, SD = .18; $M_{Old} = .30$, SD = .17) images compared with older adults, $F(1, 60) = 16.33$, $p < .001$, η2G =.21. The younger and older adults did not significantly differ for neutral images, ($M_{young} = .23$, SD = .11; $M_{Old} = .19$, SD = .11), $F(1, 60) = 1.71$, $p = .19$, η2G = 0.03.

Table 4.2
Corrected recognition scores for younger and older adults for positive, negative and neutral images

Group	Valence	N	mean	sd
Old	Negative	37	0.30	0.17
	Positive	37	0.18	0.11
	Neutral	37	0.19	0.11
Young	Negative	25	0.48	0.18
	Positive	25	0.26	0.12
	Neutral	25	0.23	0.11

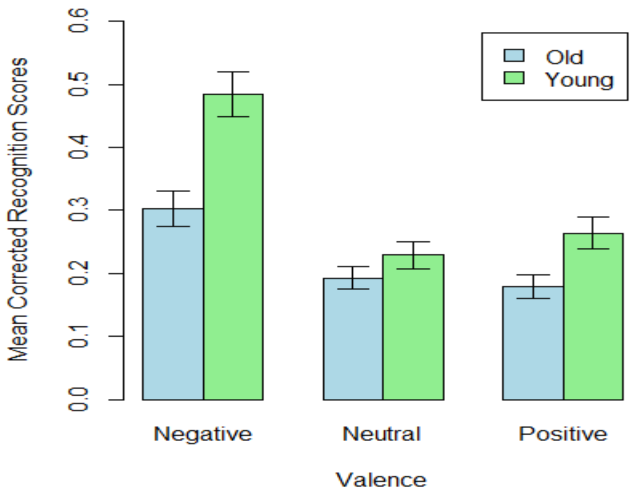

Figure 4.4. Mean corrected recognition scores for negative, neutral and positive images for younger and older adults. Error bars represent standard errors.

Effects of age on the positivity score. To further explore the significant interaction in the ANOVA, a memory positivity score (corrected recognition scores of negative images subtracted from the corrected recognition scores of positive images) was obtained. This score allowed us to examine whether there was a greater benefit for positive versus negative images in memory for older adults compared to younger ones. A t-test revealed a greater positivity score for older adults compared to younger adults, $t(60) = 2.63$, $p = .01$, $d = .68$. The positivity score was not significantly correlated with age within the older adults, $r = .31$, $p = .07$ (see Figure 4.5).

4.4.3 Rating Task

A 3 (valence: negative vs. neutral vs. positive) x 2 (group: young vs. old) x 2 (image type: old vs. foil) ANOVA on the valence ratings of images was conducted. No main effect of age group was found ($p = .09$) or any group interactions ($ps > .59$) suggesting that both

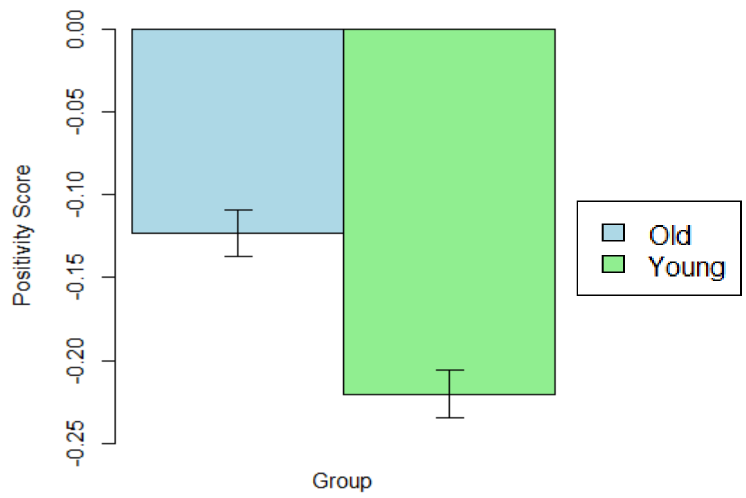

Figure 4.5. Mean corrected recognition scores for negative images subtracted from mean corrected recognition scores for positive images for younger and older adults. Error bars represent standard errors.

younger and older adults rated the images similarly in terms of their valence (see Table 4.3 for means and standard deviations). However, a significant main effect of valence was found. A post-hoc test using Tukey's correction revealed that younger and older adults alike rated positive images (M = 6.58, SD = .66; M_{young} = 6.45, SD =.69; M_{old} = 6.66, SD = .64) as significantly more positive than negative (M = 3.00, SD = .67; M_{young} = 2.98, SD = .73; M_{old} = 3.02, SD = .71) and neutral images (M = 5.13, SD = .32; M_{young} = 5.06, SD = .16; M_{old} = 5.17, SD = .39, *ps* < .001). Similarly, both younger and older adults rated negative images as significantly more negative then neutral images, $p < .001$.

Table 4.3

Means and standard deviations for the image rating task for younger and older adults

			New Images		*Old Images*		**Overall**	
Group	**Valence**	**N**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Old	Negative	42	3.04	0.72	2.99	0.70	3.02	0.71
	Neutral	42	5.15	0.43	5.19	0.36	5.17	0.39
	Positive	42	6.63	0.66	6.69	0.62	6.66	0.64
Young	Negative	25	3.03	0.65	2.93	0.62	2.98	0.63
	Neutral	25	5.05	0.15	5.06	0.16	5.06	0.16
	Positive	25	6.41	0.72	6.50	0.66	6.45	0.69

Supplementary analysis that included all participants (including older adults who were initially excluded based on MMSE scores) were consistent with the results reported above (see Appendix 3, Table A4 and Figure A1 and A2 for mean corrected recognition scores and Table A5 for means and standard deviations for the image rating task).

4.5 MRI results

Are there age-related differences in general amygdala, vmPFC and pgACC activation between younger and older adults?

4.5.1 General Amygdala Activation

Two 2 (group: old vs. young) X 2 (valence: positive > neutral vs. negative > neutral) repeated measures ANOVAs were run separately for the left and right amygdala. The analyses revealed significant group by valence interactions for both the left and right amygdala, $F(1, 54) = 8.67$, $p <.001$, $\eta^2G = .05$; $F\ (1, 54) = 20.91$, $p < .001$, $\eta^2G = .05$, respectively. Younger adults had significantly higher amygdala activation for negative over neutral images (left amygdala: $M_{neg > neu} = 25.62$, SD = 16.58; right amygdala: $M_{neg > neu} =$ 29.57, SD = 15.91) than positive over neutral images (left amygdala: $M_{pos > neu} = 7.70$, SD = 10.93; right amygdala: $M_{pos > neu} = 8.98$, SD = 14.22) while there were no significant differences found within older adults (left amygdala: $M_{neg> neu} = 12.55$, SD = 13.78; $M_{pos > neu}$ = 7.04, SD = 10.69; right amygdala: $M_{neg > neu} = 12.82$, SD = 14.22; $M_{pos> neu} = 6.65$, SD = 14.07 see Table 4.4; Figure 4.6). Therefore, as we predicted, compared to younger adults, older adults showed a selective reduction in amygdala activity to negative but not to positive images. Significant main effects of group also found that compared to older adults, younger adults exhibited greater overall left and right amygdala activity, $F\ (1,54) = 5.79$, $p = .04$, $\eta^2G = .06$ and $F\ (1,54) = 9.32$, $p = .014$, $\eta^2G = .10$, respectively.

4.5.2 General vmPFC and pgACC Activation

Two 2 (group: old vs. young) X 2 (valence: positive > neutral vs. negative > neutral) repeated measures ANOVAs were run for the vmPFC and pgACC separately. No significant effects were found for the vmPFC, *p*s > .10. However, the analyses for the pgACC revealed a main effect of valence, F (1, 54) = 11.53, p = .001, η2G = .05. Contrary to our hypothesis, there were no age-related differences. Instead, activation in the pgACC in younger and older adults was greater for positive > neutral (Younger adults: M = 31.18, SD = 41.78; Older adults: M = 12.80, SD = 21.09) than for negative > neutral (Younger adults: M = 8.57, SD = 44.40; Older adults: M = 5.12, SD = 27.35; see Table 4.4; Figure 4.6) images. There were no significant main effects of group, p = .17 or a significant interaction, p = .10.

Table 4.4

Means and standard deviations for younger and older adults for the positive>neutral and negative>neutral contrasts for the left and right amygdala, vmPFC and pgACC.

		Old (n = 38)		***Young (n = 23)***	
ROI	**Valence**	***M***	**SD**	***M***	**SD**
Left Amygdala	positive > neutral	7.0	10.7	7.7	10.9
	negative > neutral	12.6	13.8	25.6	16.6
Right Amygdala	positive > neutral	6.65	14.07	8.98	14.22
	negative > neutral	12.82	13.88	29.57	15.91
vmPFC	positive > neutral	15.55	19.43	27.05	29.72
	negative > neutral	12.65	19.44	19.70	37.48
pgACC	positive > neutral	12.80	21.09	31.18	41.78
	negative > neutral	5.12	27.35	8.57	44.40

4.5.3 Amygdala Time Course Activation

Are there age-related differences in the time course of the amygdala, vmPFC and pgACC?

Two 2 (group: old vs. young) X 2 (valence: positive vs. neutral vs. negative vs. neutral) repeated measures ANOVAs were run for the habituation index *b'* for the left and right amygdala separately. The results for the left and right amygdala revealed no significant main effects of group, valence or interaction, *ps* > .12 (see Table 4.5; Figure 4.6). Contrary to our expectation, both older and younger adults demonstrated similar right and left amygdala activation over time to negative > neutral blocks and to positive > neutral blocks.

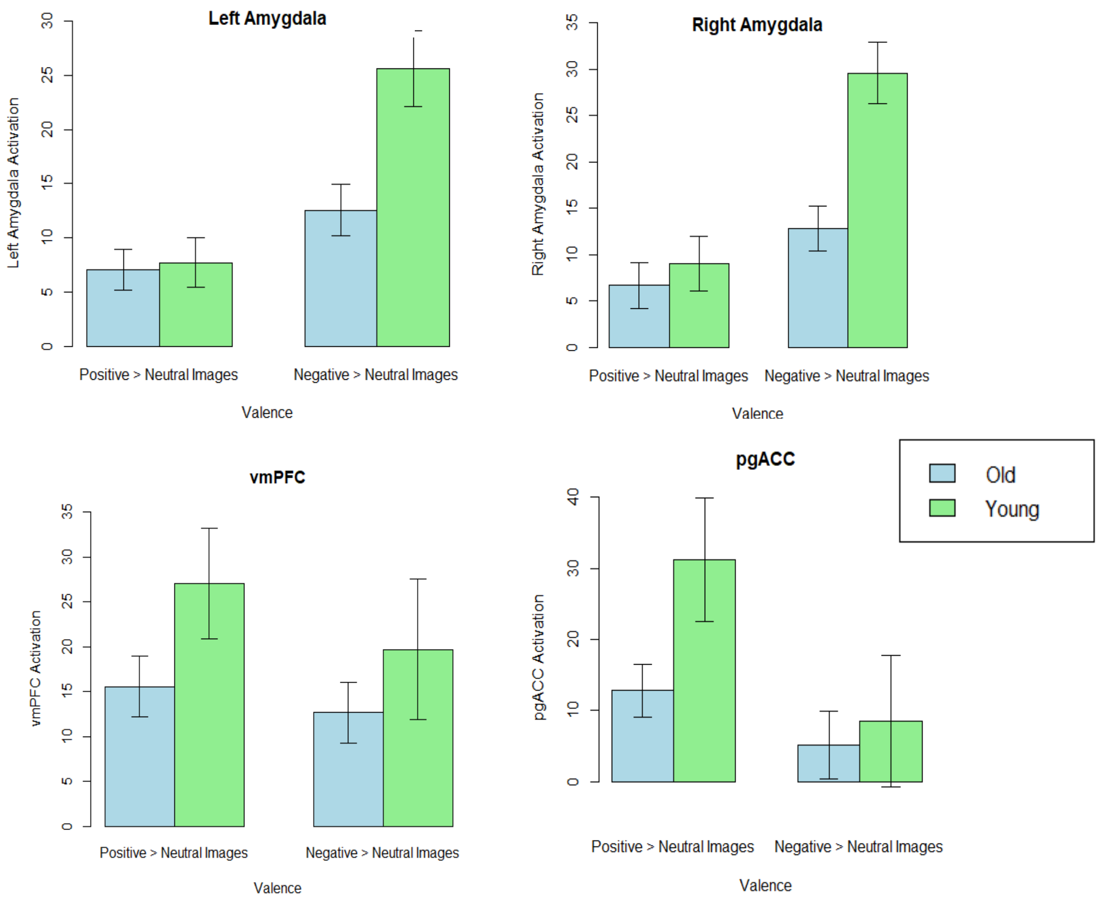

Figure 4.6. Mean β coefficients for the general activation levels of the left and right amygdala, the vmPFC and pgACC in younger and older adults for the positive>neutral and negative>neutral contrasts. Error bars represent standard error.

4.5.4 vmPFC and pgACC Time Course Activation

Two 2 (group: old vs. young) X 2 (valence: positive vs. neutral vs. negative vs. neutral) repeated measures ANOVAs were run for the habituation index *b'* for the vmPFC and pgACC separately. There were no significant main effects of group, valence or interaction for the vmPFC, *p*s > .12 and no main effects of valence or interaction for the pgACC, *p*s > .06. However, there was a main effect of group for the pgACC, F (1, 53) = 13.53, p = .002, η2G = .19. Therefore, while we expected older adults to show a larger increase in prefrontal activity over time to positive over negative images, older adults experienced a larger increase in pgACC activation over time to emotional over neutral images compared to younger adults (see Table 4.5; Figure 4.7).

Table 4.5
Means and standard deviations for younger and older adults for the time course analysis for the positive>neutral and negative>neutral contrasts for the left and right amygdala, vmPFC and pgACC.

		Old (*n* = 32)		**Young (*n* = 23)**	
ROI	**Valence**	***M***	**SD**	***M***	**SD**
Left Amygdala	positive > neutral	0.58	0.61	2.03	6.62
	negative > neutral	1.13	7.39	5.02	7.00
Right Amygdala	positive > neutral	0.39	11.57	1.45	11.16
	negative > neutral	1.09	12.41	4.64	13
vmPFC	positive > neutral	4.69	8.65	-0.08	12.73
	negative > neutral	5.65	19.12	-4.1	25.05
pgACC	positive > neutral	11.39	19.25	-8.63	26.56
	negative > neutral	13.12	22.81	-18.67	40.05

Supplementary analysis that included all participants (including older adults who were initially excluded based on MMSE scores) were consistent with the results reported above (see Appendix 3; Tables A6, A7 and Figures A3 and A4).

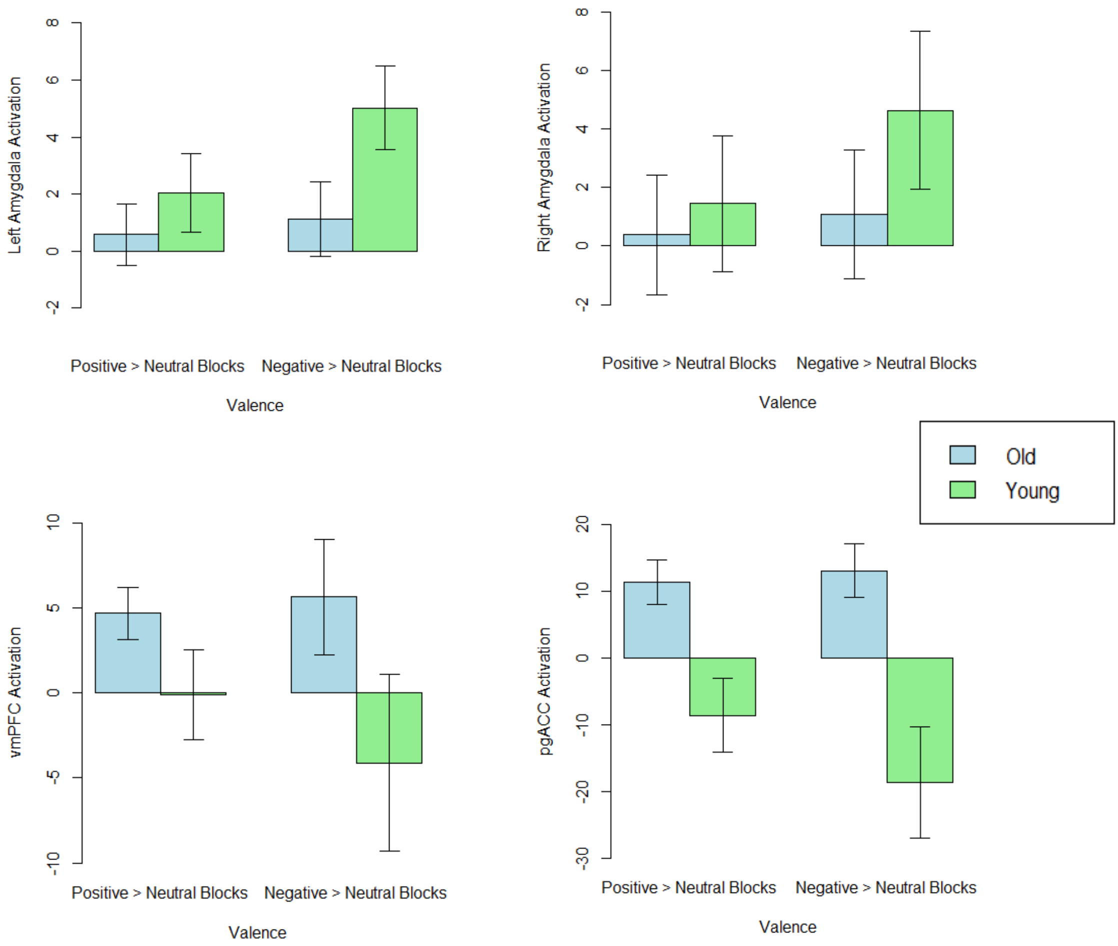

Figure 4.7. Mean β coefficients for the time course analysis for the left and right amygdala, the vmPFC and pgACC in younger and older adults for the positive>neutral and negative>neutral contrasts. Error bars represent standard error.

4.6 Discussion

The current study investigated the positivity effect in younger and older adults by examining the neural mechanisms that have previously been implicated in the literature, namely the amygdala and the medial PFC (including the vmPFC and pgACC), and the long-term memory performance for positive, negative and neutral images. We firstly aimed to replicate previous findings of the age-related positivity effect in both behavioural and neural measures, expecting to see a selective reduction in amygdala activity in response to negative images among older adults in addition to greater activation within the prefrontal regions (e.g. vmPFC and pgACC). We also expected to see this pattern reflected in our behavioural measure i.e. a preference in long-term memory for positive over negative images in older adults. Secondly, based on the socioemotional selectivity theory and the cognitive control model, we examined the neural time course of the amygdala, vmPFC and pgACC to determine whether there were different patterns of temporal change between younger and older adults which could reflect the gradual emergence of older adults implementing top-down emotional goals to regulate mood.

We successfully replicated previous behavioural findings which show that older adults demonstrate a preference for positive over negative information in memory. Although both younger and older adults remembered significantly more negative images overall, older adults benefited more from positive than negative images compared to younger adults. In other words, when computing a difference score by subtracting the corrected recognition scores for negative images from the corrected recognition scores for positive images, the difference was significantly smaller in older than in younger adults. Across the literature, the positivity effect can be defined as A) when there is an increased preference for positive over negative information in older adults compared with younger adults (Reed & Carstensen, 2012) or B) when there is a reduction in the negativity bias that is commonly observed in younger adults (Cacioppo et al., 2011; Labouvie-Vief, Lumley, Jain, & Heinze, 2003). Here, since older adults still demonstrated superior memory for negative over positive information our results suggest that older adults are exhibiting a reduction in the negativity bias. The reason for this finding could due to the constraints included within our study. For example, in the meta-analysis conducted by Reed et al. (2014), they highlight that the positivity effect is strongest when processing is unconstrained. However, in our study, since the duration of our encoding task was relatively long (around 30mins), we required participants to indicate whether each image was an indoor or an outdoor scene to keep participants engaged. This however, meant that their attention was divided between processing the emotion and processing the question which could be the reason for not finding an increased preference for positive information as others have previously reported (e.g. Mather et al., 2004). Another possibility could be the duration between the emotional processing task and our memory recognition test. Many of the studies included in Reed et al.'s meta-analysis used durations of 24h or less whereas we examined memory a week later in order to avoid any ceiling effects since emotional images are known to yield high levels of accuracy (Dolcos, Labar, & Cabeza, 2005). In fact, to our knowledge, there are only a small number of studies examining the positivity effect that have administered the memory test a week later (Fernandes, Ross, Wiegand, & Schryer, 2008; Ford, DiBiase, Ryu, & Kensinger, 2018; Leal, Noche, Murray, & Yassa, 2016; Speirs, Belchev, Fernandez, Korol, & Sears, 2018; Tournier, Jordan, & Ferring, 2016) and results from these studies offer mixed support for the positivity effect. Nevertheless, despite imposing experimental constraints during the encoding task and having a longer retrieval interval, we still provide evidence of the positivity effect and a medium effect size.

According to the current literature, one possibility for seeing behavioural evidence of the positivity effect is due to older adults implementing goal-directed attention that allows them to direct their attention away from negative information and towards more positive information. As such, it is hypothesized that older adults will demonstrate lower levels of amygdala activation to negative stimuli and greater levels of prefrontal activity to emotional stimuli (Leclerc & Kensinger, 2008; Wright, Wedig, Williams, Rauch, & Albert, 2006). Consistent with this prediction, our general activation analysis for the amygdala revealed a group by valence interaction. More specifically, younger adults demonstrated significantly higher overall left and right amygdala activation for negative > neutral images over positive > neutral images whereas no such differences were found among older adults. This result is consistent with previous research whereby older adults, compared to younger adults, show reductions in amygdala activation to negative stimuli (Gunning-Dixon et al., 2003; Iidaka et al., 2002; Mather et al., 2004). However, we did not find age-related differences in prefrontal activity that are also commonly reported alongside a reduction in amygdala activation (Gunning-Dixon et al., 2003; Tessitore et al., 2005; Williams et al., 2006). Instead, we found valence specific effects; that is, pgACC activation was greater for positive > neutral images than negative > neutral across younger and older adults which is inconsistent with previous studies that have found greater prefrontal activity to negative than positive information in younger but not older participants (Leclerc & Kensinger, 2008; Ritchey, Bessette-Symons, Hayes, & Cabeza, 2011). Taken together, these results are consistent with the SST and the aging brain model's predictions; that the positivity effect in aging arises due to a reduction in amygdala activity to negative but not positive stimuli. However, what is not clear from the current results is whether this specific reduction in amygdala activity to negative stimuli is a consequence of more controlled emotional processing in older adults since our pgACC and vmPFC results indicate there were no group differences. Instead, across younger and older adults, pgACC activation was significantly higher for positive than negative images.

One important advantage of the current study however is that we also modelled changes in neural activity over time. Previous studies have found age-related differences in early versus late stages of emotional processing (e.g. Allard & Kensinger, 2014; Roalf et al., 2011) which have been considered to reflect the implementation of cognitive control over time which may lead to the positivity effect. We expected older adults to exhibit a reduction in amygdala activation over time specifically to negative images as well as a gradual increase in prefrontal activation to emotional stimuli. Partly consistent with our prediction, older adults did experience a greater increase in pgACC activity over time compared to younger adults. This was *not* specific to negative or positive valence as has previously been found (Leclerc & Kensinger, 2008; Williams et al., 2006) but rather to emotional images more generally.

However, we did not find a reduction in amygdala activation as expected. Instead, we found that both younger and older adults experienced similar left and right amygdala activation to emotional images over time. Collectively, these results suggest that older adults relied more heavily on prefrontal regions during emotional processing than younger adults did and support the findings of previous studies which found similar patterns of prefrontal activity during emotional processing (e.g. Roalf et al., 2011). Since the pgACC has been implicated as an important area that mediates cognitive control and emotional processing (Ochsner & Gross, 2005; Pessoa, 2009), it is possible that the changes in pgACC activation among older adults over time indicate a gradual shift towards implementing cognitive control. As such, these findings possibly reflect the greater amount of time older adults need in order to implement more controlled emotional processing. For example over the course of the experiment, older adults may have begun to spontaneously engage in the down-regulation of negative affect (Corbett, Rajah, & Duarte, 2020) or the up-regulation of positive affect which subsequently allowed them to reduce their negativity bias in memory and demonstrate the positivity effect.

Therefore, our neural findings do not support previous research suggesting that the positivity effect is an automatic process evident early on during emotional processing as others have previously claimed (Hilimire et al. 2014; Johnson et al., 2013). Rather, our results suggest that the positivity effect is a time-dependent process that requires older adults to engage areas responsible for cognitive control and/or emotion regulation over time. In other words, our results suggest that older adults may still automatically process negative over positive stimuli (which is partly evidenced in their memory performance and in our amygdala activity results) but over time, override this tendency and utilize prefrontal regions to implement emotional regulation strategies to increase positive affect/ decrease negative affect. However, it is worth highlighting that the time course analysis on our memory recognition data (reported in Appendix 2; 4.8.2.2) is inconsistent with this interpretation. If the gradual increase in activation among the prefrontal regions enabled older adults to concentrate more on positive stimuli and ignore negative stimuli, then we would have expected to find an age by valence interaction in which memory performance was greater for positive over negative images that were presented in later versus earlier blocks. However, we failed to find any significant differences.

Meanwhile, while we saw an increase in prefrontal activity, we did not see an associated decrease in amygdala activity specifically to negative images over time. In other words, our results do not support previous findings in which prefrontal activity in the vmPFC for example, is frequently coupled with a decrease in amygdala activity (Sakaki et al., 2013; St. Jacques et al., 2010; Urry et al., 2006). This is perhaps surprising since, as Kensinger previously highlighted in a review (Kensinger & Leclerc, 2009), studies that have allowed participants longer viewing times (e.g. > 400ms) are often more likely to find robust age-related differences (e.g. Gunning-Dixon et al., 2003; Williams et al., 2006) whereas those with shorter image presentation durations (e.g. 200ms) are not (e.g., Wright et al., 2006). In the present study, each image within a valence block was presented for 3000ms which according to this theory, should have been enough time for older adults to implement top-down regulation. Nevertheless, the valence-specific finding of the right amygdala dovetails nicely with our behavioural results in which negative images were remembered better by both younger and older participants and suggests that older adults' long-term memory equally benefits from increased amygdala activation during encoding (McGaugh, 2004).

Finally while our study has several strengths, there are important limitations to consider too. Firstly, like Roalf et al. (2011), we did not measure the anatomical volume of amygdala, vmPFC or pgACC but acknowledge that these regions are known to change with aging. For example, some researchers have found that the amygdala volume declines with age (Malykhin, Bouchard, Camicioli, & Coupland, 2008). Therefore it could be argued that our results reflect structural differences in the amygdala. However, since we found similar patterns of amygdala and prefrontal activation among younger and older adults across our general and time course analyses, our results indicate otherwise and suggest that the functionality of these areas was preserved. Secondly, among our older adults, the gender balance was roughly equal between males and females but among our younger participants, there were significantly more females. This is important to highlight when previous research has identified sex differences in emotional processing. For example, women have been found to respond more strongly to negative emotional stimuli and often show greater left amygdala activation to negative stimuli whereas the opposite is true for men (for a review see Stevens & Hamann, 2012). As such, some of our differences may be being driven by the greater proportion of female participants in our study across both younger and older adults. Therefore it will be important for future research to match younger and adults more closely on sex. Thirdly, our older adults reported significantly higher feelings of positive affect at the start of the first experimental session one as well as significantly lower levels of negative affect and depressive symptoms compared to younger adults. Therefore, it is possible that these differences in mood influenced the way in which participants responded to each experimental task. While there is no clear evidence that older adults performed differently to younger adults on the encoding task (based on reaction times and judgements), positive and negative emotional states have been differentially associated with the processing of stimuli (e.g. the Affect-as-Information Framework: Schwarz & Clore, 1983). According to the mood-congruent-memory effect, when individuals are in a positive mood, they are more likely dedicate attentional resources to positive information and engage in more elaborative processing which may lead to enhanced memory for positive stimuli (Bower, 1981). For example, stimuli that is congruent with a person’s current mood is learned more easily

(Singer & Salovey, 1988). Furthermore, at the start of the second experimental session, older adults reported significantly higher levels of positive affect and lower levels of depressive symptoms which may have influenced retrieval since stimuli that is congruent with an individuals' current mood is also more easily recalled (B. G. Knight, Maines, & Robinson, 2002).

To conclude, the present research provides behavioural and neural evidence of age-related differences in emotional processing and offers more support for the SST and cognitive control theory than the aging brain model. While our results do not provide straightforward support for the SST or identify the exact neural mechanisms through which the positivity effect arises, they are consistent with previous findings in which older adults frequently show a selective reduction in amygdala activity to negative stimuli (Erk et al., 2008; Iidaka et al., 2002; Mather et al., 2004). More importantly, they offer tentative support for the cognitive control model and suggest that the positivity effect seen in memory could be a consequence of age-related differences in the activation of prefrontal regions over time. In other words, they suggest that older adults relied more heavily on controlled emotional processing over time than younger adults did which may have allowed them to focus their attention away from negative images and toward positive images. However, it is important to highlight that we did not find a gradual decline in amygdala activity among older adults specifically to negative images as the SST and cognitive control theory would predict. Moreover, we did not report a separate measure of executive functioning that may reflect cognitive control capabilities, meaning it is unclear whether the magnitude of the positivity effect is greater among those individuals who score more highly on cognitive control measures which would be consistent with the cognitive control model's predictions. Consequently, future studies should consider examining behavioural measures of executive functioning when examining the positivity effect in order to strengthen this argument.

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4.8 Appendices

4.8.1 Appendix 1: Demographic Table Including All Participants

Table A1
Demographic measures and results in cognitive and self-reported questionnaires from Day 1.

	Behavioural Analysis		**MRI analysis**	
	Young n = 25	*Old* n = 42	*Young* n = 23	*Old* n = 38
Mean Age (in years)	19.6 (1.7)	66.79 (9.37)	19.61 (1.78)	66.42 (9.48)
Age range (in years)	18-26	50-87	18-26	50-87
Sex (females/males)	18/7	22 / 20	16/7	21 / 17
Education (in years)	13.72 (1.72)	14.38 (3.33)	13.65 (1.72)	14.39 (3.12)
MMSE	-	27.78 (1.91)	-	27.71 (1.96)
Positive Affect	28.16 (7.24)	35.58 (8.04)	28.65 (7.35)	36.08 (7.78)
Negative Affect	13.56 (5.12)	11.35 (1.85)	12.74 (2.58)	11.17 (1.78)
CES-D	15.60 (11.72)	7.34 (7.03)	14.82 (10.96)	6.76 (6.46)

4.8.2 Appendix 2: Supplementary Results

4.8.2.1 Supplementary Behavioural Data Analysis

Encoding task accuracy. Participants' responses in the encoding tasks and the corresponding reaction times were analysed to determine if there were any significant differences between younger and older adults. For the encoding task, in which participants had to identify whether the image was indoor or outdoor, an accuracy score for each image type was calculated for each participant andfor each valence category separately by averaging the number of correct responses. Likewise, average reaction times were calculated for each trial type (indoor versus outdoor), for each participant for each valence.

Memory test. For the memory recognition task, average reaction times were calculated for each participant, for each image type ('old' vs. 'foil') and for each valence.

Memory time course analysis. In order to examine whether older adults memory for positive images benefitted from later trials in the encoding phase, we conducted a time course analysis similar to that for the neural activation on memory performance for images shown during the scanning session. Here, a memory accuracy score (the average of correctly remembered images) for blocks 1 – 9 for each valence was calculated. From this, average memory accuracy, "Y", was then predicted by the log transformed block number "X". Therefore like before, blocks 1-9 were transformed using natural logarithm to 0, 0.69, 1.10, 1.39, 1.61, 1.79, 1.95, 2.08 and 2.20.

4.8.2.2 Supplementary Behavioural Results

Encoding Task.

Effect of age and valence on encoding task accuracy. A 3 (valence: negative vs. neutral vs. positive) x 2 (group: young vs. old) x 2 (scene type: indoor vs. outdoor) analysis of variance (ANOVA) was carried out on the accuracy of the encoding task; deciding whether the image depicted an indoor or outdoor scene. No main effects of group or interaction between group and valence or group and scene type were found (ps > .29), suggesting that younger and older adults performed similarly in the encoding phase.

However, main effects of valence, $F(2,120) = 130.97$, $p <. 001$, $\eta^2G = .25$, and of scene type, $F(1, 60) = 139.89$, $p < .001$, $\eta^2G = .44$, were found as well a significant interaction between valence and scene type, $F(2, 120) = 62.14$, $p < .001$, $\eta^2G = .18$. Subsequent analysis separately conducted for each scene type revealed significant effects of valence for both indoor, $F(2, 120) = 113.72$, $p < .001$, $\eta^2G = .40$ and outdoor scenes, $F(2, 120) = 4.78$, $p = .01$, $\eta^2G = .04$. For both indoor and outdoor scenes a Tukey post-hoc test revealed that the accuracy was greater for positive images ($M_{indoor} = 0.90$, SD = .06; $M_{outdoor} = .96$, SD = .03; see Table A2) compared to negative images ($M_{indoor} = 0.75$, SD = .10; $M_{outdoor} = .94$, SD = .04). In addition, for indoor scenes, accuracy levels for negative images ($M = .75$; $SD = .10$) were significantly lower than that for neutral images ($M = .88$, $SD = .08$,

$p < .001$). However, accuracy rates between positive and neutral images were comparable ($p = .6$).

Furthermore, when analyses were conducted separately for each valence condition, significant main effects of scene type were found for positive, $F(1, 60) = 40.45$, $p < .001$, $\eta^2G = .28$, negative, $F(1, 60) = 175.41$, $p < .001$, $\eta^2G = .63$ and neutral images, $F(1, 60) = 47.86$, $p < .001$, $\eta^2G = .30$. Accuracy for indoor images was poorer than accuracy for outdoor images across all valences ($M_{indoor} = .84$, $SD_{indoor} = .11$; $M_{outdoor} = .95$, $SD_{outdoor} = .04$). These results suggest that both younger and older participants were poorer to correctly identify negative images that depicted an indoor scene. Given that the valence effects were not significantly qualified by age, it is unlikely that they would lead to systematic group differences in the fMRI data.

Effect of age and valence on reaction times during encoding task. A 3 (valence: negative vs. neutral vs. positive) x 2 (group: young vs. old) x 2 (scene type: indoor vs. outdoor) ANOVA was carried out on the reaction times for the encoding task. Only a main effect of scene type, $F(1, 60) = 159.68$, $p < .001$, η2G = .18 and valence, $F(2, 120) = 252.5,3$ $p < .001$, η2G = .23 were found. Across younger and older participants, reaction times were significantly slower on trials in which the image depicted an indoor scene ($M_{indoor} = 1265$ms, SD = 229; $M_{outdoor} = 1081$ms, SD = 205; see Table A2). A Tukey post-hoc test revealed that participants' reaction times were significantly slower on negative trials ($M = 1322$ms, SD = 233) compared to both positive ($M = 1089$ms, SD = 203, $p < .001$) and neutral trials ($M = 1108$ms, SD = 195, $p < .001$). However, these effects were not significantly interacted with group ($p = .23$). These results suggest that there are no systematic differences in encoding performance between younger and older adults**.**

Table A2

Mean accuracy and reaction times (ms) during encoding task for negative, neutral and positive indoor and outdoor scene types.

	Scene Type	Valence	Younger (*n* = 25) *M* (SD)	Older (*n* = 37) *M* (SD)
Accuracy	Indoor	Negative	0.72 (0.09)	0.76 (0.10)
		Neutral	0.85 (0.09)	0.89 (0.06)
		Positive	0.89 (0.07)	0.90 (0.05)
	Outdoor	Negative	0.94 (0.03)	0.94 (0.04)
		Neutral	0.96 (0.03)	0.94 (0.03)
		Positive	0.96 (0.02)	0.95 (0.03)
Reaction Time (*ms*)	Indoor	Negative	1437 (185)	1403 (247)
		Neutral	1226 (125)	1193 (203)
		Positive	1187 (162)	1159 (228)
	Outdoor	Negative	1260 (179)	1203 (214)
		Neutral	1056 (152)	977 (159)
		Positive	1062 (157)	970 (167)

Memory

False Alarm Rates in Memory Recognition Test. A 3 (valence: negative vs. neutral vs. positive) x 2 (group: young vs. old) ANOVA on the false alarm rates (endorsing an image as 'old' when it is in fact 'new' or vice versa) for trials in the memory test showed a main effect of group, $F(1,61) = 12.52$, $p < .001$, $\eta^2G = .14$; More specifically, older adults demonstrated higher levels of false alarm rates than younger adults did ($M_{young} = .11$, SD = .11; $M_{old} = .22$, SD = .16). In addition, we found a significant main effect of valence, $F(2,122) = 16.56$, $p < .001$, $\eta^2G = 0.06$ but no significant interaction, $p = .06$. A Tukey post-hoc test revealed that participants' false alarm rates were significantly higher for negative (*M* = .27, SD = .19) than neutral images (*M* = .16, SD = .12), $p = .001$. No significant differences were found between positive (*M* = .24, SD = .15) and negative images, $p = .07$ or between positive and neutral images, $p = .38$. Therefore, while older adults had higher overall false alarm rates, both younger and older adults had higher false alarm rates for negative compared to neutral images but similar false alarm rates between positive and negative images.

Memory Time Course Analysis. We tested whether primacy and recency effects in memory performance were differentially modulated by age (young vs. old) and by valence category (positive vs. neutral vs. negative vs. neutral) and computed a 2 (group: old vs. young) X 2 (valence: positive vs. neutral vs. negative vs. neutral) repeated measures ANOVA on the memory accuracy scores (see Table A3 for raw means and standard deviations). In this analysis, a negative value would indicate that participants remembered significantly more images that were presented in the earlier encoding trials whereas a positive value would indicate that participants remembered significantly more images that were presented in later trials. The results revealed no significant main effects of group, valence or an interaction, *p*s > .1.

Table A3

Model estimated means and standard deviations for younger and older adults for the time course analysis on memory performance for corrected recognition scores.

Group	Valence	N	Mean	SD
Old	Negative	32	0.30	2.64
	Positive	32	0.24	2.33
	Neutral	32	0.47	5.66
Young	Negative	23	-0.50	2.59
	Positive	23	-0.41	2.01
	Neutral	23	-0.68	4.97

4.8.3 Appendix 3: Supplementary tables and figures for analysis including all participants

The following tables and figures include data from all participants including older adults who were previously excluded based on their MMSE score (less than 26/30). The participants included 42 older adults (22 females; age range: 50-87, *M*age = 66.79, SD = 9.37) and 25 younger adults (18 females; age range: 18-26; *M*age = 19.6, SD = 1.76; see Table A1). For the MRI results, the participants included 38 older adults (21 females; age range: 50-87, *M*age = 66.42, SD = 9.48; MMSE range 22-30, *M*= 27.71, SD = 1.96; see Table A1) and 23 younger adults (16 females; age range: 18-26, *M*age = 19.61, SD = 1.78).

4.8.3.1 Table of corrected recognition scores for younger and older adults

Table A4
Corrected recognition scores for younger and older adults for positive, negative and neutral images

Group	Valence	N	mean	sd
Old	Negative	42	0.30	0.16
	Positive	42	0.17	0.10
	Neutral	42	0.19	0.11
Young	Negative	25	0.48	0.18
	Positive	25	0.26	0.12
	Neutral	25	0.23	0.11

4.8.3.2 Figure of corrected recognition scores for younger and older adults

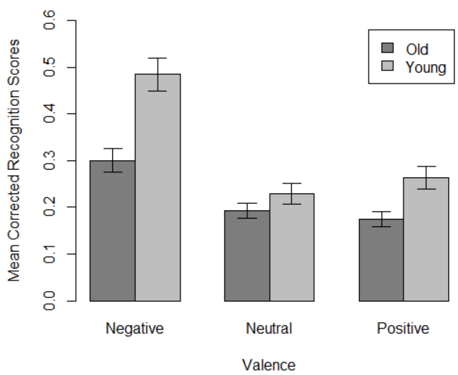

Figure A1. Mean corrected recognition scores for negative, neutral and positive images for younger and older adults. Error bars represent standard errors.

4.8.3.3 Figure of corrected recognition scores for younger and older adults

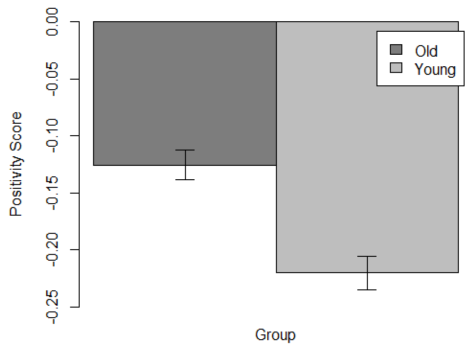

Figure A2. Mean corrected recognition scores for negative images subtracted from mean corrected recognition scores for positive images for younger and older adults. Error bars represent standard errors.

4.8.3.4 Table of means and standard deviations for the image rating task for younger and older adults

Table A5

Means and standard deviations for the image rating task for younger and older adults

			New Images		*Old Images*		**Overall**	
Group	**Valence**	**N**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Old	Negative	42	2.94	0.76	2.90	0.71	2.92	0.73
	Neutral	42	5.18	0.42	5.22	0.35	5.20	0.38
	Positive	42	6.71	0.71	6.77	0.67	6.74	0.69
Young	Negative	25	3.03	0.65	2.93	0.62	2.98	0.63
	Neutral	25	5.05	0.15	5.06	0.16	5.06	0.16
	Positive	25	6.41	0.72	6.50	0.66	6.45	0.69

4.8.3.5 Table of means and standard deviations for the general MRI results for younger and older adults

Table A6

Means and standard deviations for younger and older adults for the positive>neutral and negative>neutral contrasts for the left and right amygdala, vmPFC and pgACC.

		Old (*n* = 38)		**Young (*n* = 23)**	
ROI	**Valence**	***M***	**sd**	***M***	**sd**
Left Amygdala	positive > neutral	7.11	10.21	7.7	10.93
	negative > neutral	11.73	13.11	25.62	16.58
Right Amygdala	positive > neutral	6.44	14.13	8.98	14.22
	negative > neutral	12.39	13.11	29.57	15.91
vmPFC	positive > neutral	14.45	19.15	27.05	29.72
	negative > neutral	12.12	18.87	19.7	37.48
pgACC	positive > neutral	11.3	21.25	31.18	41.78
	negative > neutral	4.28	26.15	8.57	44.4

4.8.3.6 Figure of means beta coefficients for the general MRI results for younger and older adults

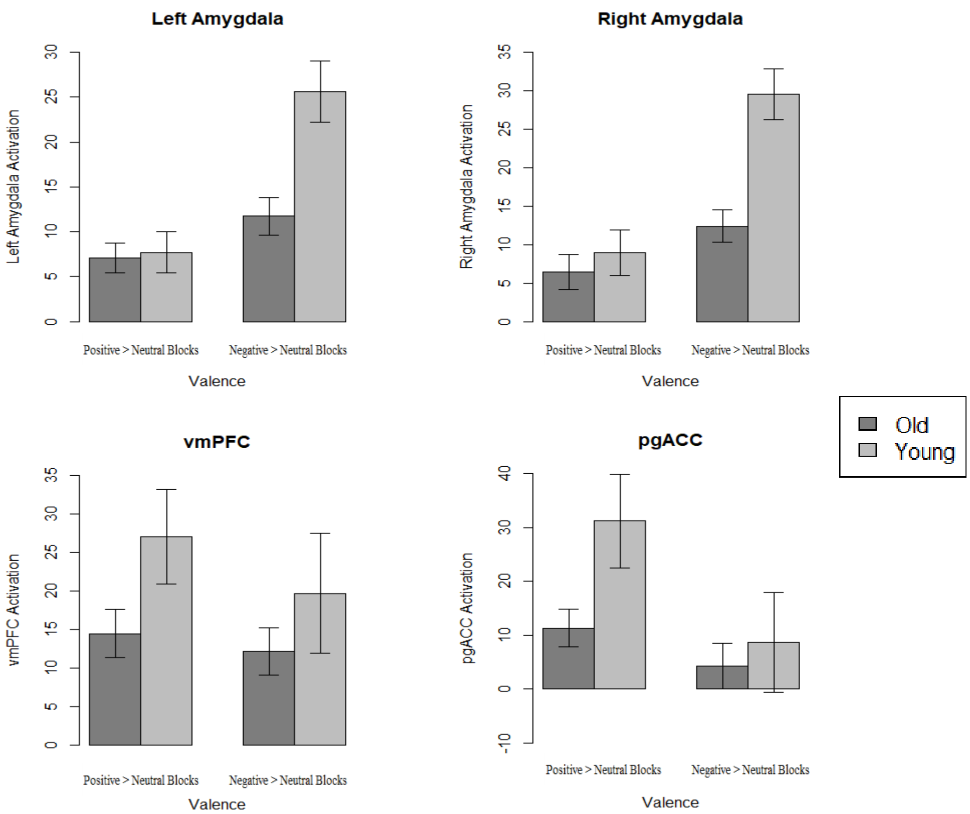

Figure A3. Mean β coefficients for the general activation levels of the left and right amygdala, the vmPFC and pgACC in younger and older adults for the positive>neutral and negative>neutral contrasts. Error bars represent standard error.

4.8.3.7 Table of means and standard deviations for the MRI time course analysis results for younger and older adults

Table A7

Means and standard deviations for younger and older adults for the time course analysis for the positive>neutral and negative>neutral contrasts for the left and right amygdala, vmPFC and pgACC.

		Old (n = 37)		Young (n = 23)	
ROI	**Valence**	***M***	**sd**	***M***	**sd**
Left Amygdala	positive > neutral	0.58	6.11	2.03	6.62
	negative > neutral	1.13	7.39	5.02	7.00
Right Amygdala	positive > neutral	0.20	12.41	1.68	12.28
	negative > neutral	1.23	13.65	4.49	14.21
vmPFC	positive > neutral	6.06	21.57	-5.76	28.54
	negative > neutral	4.42	8.98	-0.63	13.83
pgACC	positive > neutral	11.46	22.54	-18.86	40.04
	negative > neutral	9.99	18.80	-8.90	26.73

4.8.3.8 Figure of means beta coefficients for the general MRI results for younger and older adults

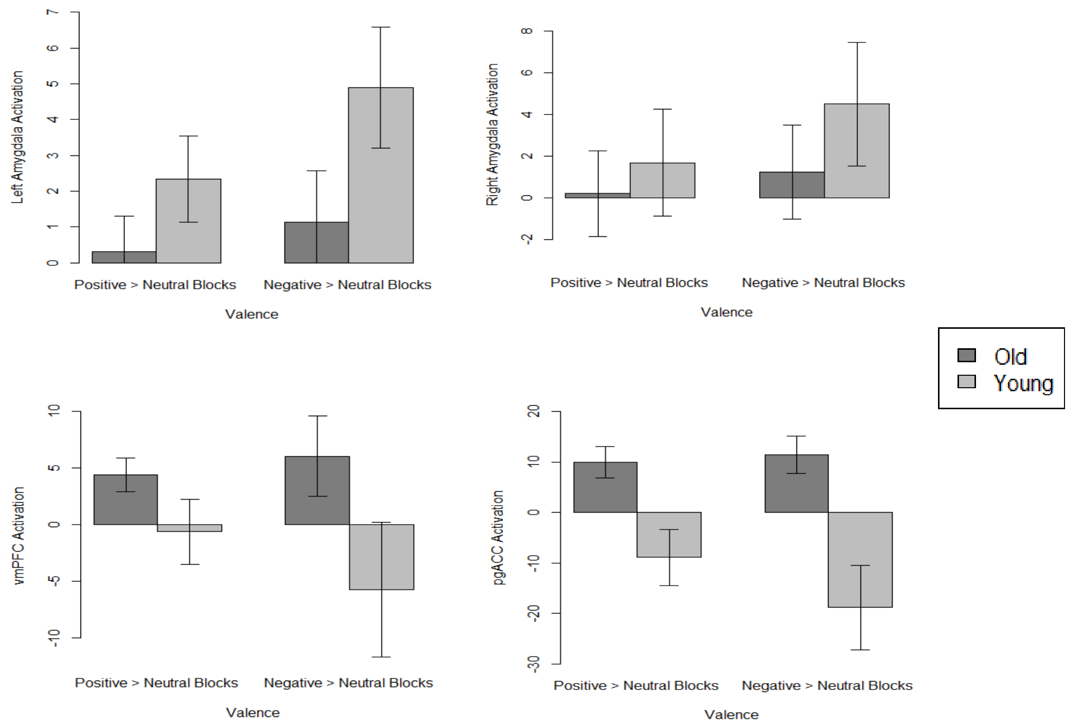

Figure A4. Mean β coefficients for the time course analysis for the left and right amygdala, the vmPFC and pgACC in younger and older adults for the positive>neutral and negative>neutral contrasts. Error bars represent standard error.

5. Chapter 5: Examining the effects of future time perspective and age across measures of subjective well-being, memory and neural activation.

5.1 Abstract

According to the Socioemotional Selectivity Theory (SST; Carstensen, 1992; Carstensen, 2006) older adults exhibit better emotional well-being compared to younger adults because of an increasing awareness that time left in life is more limited. However, a less expansive future time perspective has been associated with poorer emotional well-being, casting doubt over the SST. Moreover, few studies have investigated the relationship between future time perspective and brain activation to, or memory for, emotional stimuli. Therefore, the current study aims to test the predictions of the SST in order to understand whether future time perspective is a critical component in age-related increases in positive affect across neural and behavioural measures (including memory and emotional well-being). 21 younger adults aged between 18 and 21 and 31 older adults aged between 50 and 87 were asked to view positive, negative and neutral images inside an MRI scanner before returning a week later for a surprise memory test. In between sessions, participants were asked to complete a daily mood assessment up to three times per day. Contrary to the SST's predictions, our results indicate that a more limited future time perspective was associated with lower levels of positive affect and higher levels of negative affect across age groups. Moreover, a more limited future time perspective was not associated with greater positivity in memory among older adults. However, older adults who considered their time left in their lives to be less expansive, showed increased amygdala activation when processing positive over negative images suggesting there may be two different pathways through which future time perspective can influence emotional processing.

5.2 Introduction

When people think of advanced aging, they may think of it as being the time in life in which there is increased ill-health, bereavement and loneliness coupled with a marked decline in mental functioning. Yet despite all this, research has shown that aging is associated with an increase in the frequency of positive feelings (Carstensen et al., 2011) and in emotional well-being (Carstensen & DeLiema, 2018; Carstensen, Pasupathi, Mayr, & Nesselroade, 2000) and a decrease in negative emotions such as anger (Steptoe et al., 2015). There is a plethora of research which finds that older adults often report more positive and less negative emotion in daily life (for review, see Charles & Carstensen, 2010) and that compared to younger adults, are considered to be more emotionally stable (Carstensen et al., 2011; L. M. Williams et al., 2006). In addition to explaining the positivity effect, as mentioned in the previous chapter, the socioemotional selectivity theory (SST; Carstensen, 1992; Carstensen, 2006) is also thought to explain this increase in emotional well-being in daily life. Since the perception of time we have left in our lives diminishes with age, older adults are thought to focus less on future opportunities and instead become more aware of their limited time (Strough et al., 2016). Consequently, they prioritize more short-term goals relating to emotional well-being as a way of maximizing their time left in life as feeling positive.

However, much of the empirical support for the SST and the role of future time perspective is grounded within the social cognition literature which finds that when time horizons are manipulated to be less expansive, individuals are more likely to seek emotionally close partners that may offer emotional support (Fung & Carstensen, 2006). On the other hand, when older adults are encouraged to view their time left in life as more expansive, they show more similar behaviour to that of younger adults in terms of preferring social interactions with people unfamiliar to them (Fung, Carstensen, & Lutz, 1999). Similar patterns can be replicated in younger adults too, who when asked to view their time with their current social circle as being more limited, exhibit similar patterns to older adults in prioritizing social goals (Fung et al., 1999). As such, the perception of time is considered to be critical in influencing peoples' behaviour and suggests that when we consider our time to be more limited, we are more likely to prioritise emotionally meaningful goals.

According to the SST, this pattern, in which the perception of time influences our goals, should extend to all emotional processing and should therefore be evident in other cognitive domains including memory. Indeed, there is support for this prediction after several studies found that having a more limited future time perspective is associated with older adults' preference for positive information in memory (Barber, Opitz, Martins, Sakaki, & Mather, 2016; Kennedy, Mather, & Carstensen, 2004). Interestingly, this pattern can be also be weakened when older adults are encouraged to perceive their time as more expansive (Kellough & Knight, 2012) suggesting that memory positivity effects are also driven by a shift in future time perspective. Collectively then, these studies, along with the social cognition literature studies, suggest that it is time perspective, which can be experimentally manipulated, unlike chronological age, which leads individuals to concentrate on emotionally-gratifying socio-emotional goals and what leads to the positivity effect seen in memory. However, it is worth noting that many of the aforementioned studies investigating memory do not obtain explicit subjective measures of future time perspective and instead manipulate future time perspective through experimental instructions. Therefore, it is difficult to know whether a natural shift in an individual's time perspective due to aging is in fact the reason for these age-related differences in recall and recognition. Despite the extensive support for the SST however, more recent research has cast doubt upon whether having a more limited future time perspective is responsible for the age-related differences frequently seen in emotional well-being (see Fung & Isaacowitz, 2016 for a review). In fact, several studies have shown that a less expansive future time perspective is associated with a maladaptive emotional profile including lower psychological well-being (Demiray & Bluck, 2014) and low positive affect (Grühn, Sharifian, & Chu, 2016; Pfund, Ratner, Allemand, Burrow, & Hill, 2021) as well as depressive symptoms (Hill & Allemand, 2020) and a decrease in well-being over time (Kotter-Grühn, Kleinspehn-Ammerlahn, Gerstorf, & Smith, 2009). In one study that combined data from nine other studies that had used Carstensen and Lang's Future Time Perspective Scale (1996), the researchers found that chronological age and future time perspective had opposing effects; advanced aging was associated with higher ratings of life satisfaction, empathy and positive emotion whereas a limited future time perspective was associated with higher levels of negative affect and lower levels of positive emotion and life satisfaction (Grühn et al., 2016). In addition, several studies have investigated whether future time perspective moderates the positivity effects frequently seen in memory but found that chronological age, and not future time perspective, was associated with the positivity effect (Bohn, Kwong See, & Fung, 2016; Kan, Garrison, Drummey, Emmert, & Rogers, 2018).

Taken together, these studies highlight the limitation of using chronological age to infer a more limited future time perspective in older adults and question whether future time perspective is the key variable in explaining the age-related differences frequently seen in subjective emotional well-being and more widely in emotional processing. In addition, across many of the studies that have found a relationship between a less expansive future time perspective and the preference for choosing emotionally-gratifying goals, chronological age has not always been controlled for. When it has been included as a variable, it has been found to have a stronger and more direct effect on avoiding negative information than future time perspective (Strough et al., 2016). Therefore, it is difficult to know whether it is in fact future time perspective that is driving these differences or if it is chronological age.

Another limitation within the current literature is that aforementioned lines of research (e.g. social cognition, memory and emotional well-being), despite frequently using the SST to make predictions, have largely been studied separately. In other words, few studies have considered the effects of future time perspective on memory as well as emotional well-being within the same study. As a consequence, while the predictions of the

SST should theoretically apply to all emotional processing, the current findings from the social cognition and memory literature align with the idea that a more limited future time perspective results in increased positive affect whereas more recent findings from the emotional well-being literature yield the opposite pattern. Therefore, it is currently difficult to validate the predictions of the SST. Not only that, but there is also little evidence on the relationship between future time perspective and neural activation during the processing of emotional material. If older adults are able to obtain these short-term goals that enable them to maximise positive affect by utilising cognitive control and engaging in emotion regulation efforts, as was previously mentioned in the last chapter, then one might expect there to be a relationship between future time perspective and the areas implicated in cognitive control and emotional regulation such as the vmPFC (Leclerc & Kensinger, 2008) and the amygdala. In other words, the cognitive control extension of the SST would predict that a more limited future time perspective should be associated with the manifestation of the positivity effect in the brain i.e. stronger activation to positive over negative stimuli in the vmPFC and amygdala as has previously been found (e.g. Leclerc & Kensinger, 2008, 2010). However, to our knowledge, no previous study has directly examined this relationship.

Therefore in the current study, we use a multifaceted approach to understand the role of future time perspective on emotional processing by combining different methodological techniques to assess 1) subjective emotional well-being measures obtained outside of the laboratory 2) behavioural measures of emotional memory, and 3) neural activation during the processing of emotional stimuli. In order to investigate whether the positivity effect is evident in self-reported emotional well-being over the course of seven days, we used an experience sampling method using an iPod touch with experience sampling-software installed (iDialog Pad, see Kubiak & Krog, 2012). By asking participants about their mood and ratings of future time perspective three times per day for one week (resulting in a total of 21 data entry points if all prompts were completed), we examined whether any age-related positivity effects were associated with differences in future time perspective between younger and older adults. Expanding on previous studies, we expect that older adults, compared to younger adults, will demonstrate higher levels of emotional well-being. More specifically, we expected that older adults would report higher levels of positive emotion and lower levels of negative emotion compared to younger adults.

In addition, drawing upon the same experimental methods used in our previous chapter, we utilised our memory task data and neural activation data (please see Chapter 4 for methods) to investigate the relationship between these measures and ratings of future time perspective from our diary study among younger and older adults. While a more expansive future time perspective may be associated with better emotional well-being as seen in Grühn et al. (2016) and Kotter-Grühn et al. (2009), we predict that a limited future time perspective, will be associated with the positivity effect in memory, particularly among older adults. We also expect a similar pattern to be associated with the positivity effect in the brain i.e. stronger activation to positive over negative stimuli in the vmPFC and amygdala (e.g. Leclerc & Kensinger, 2008, 2010).

5.3 Methods

5.3.1 Participants

Participants were initially recruited for a separate MRI study (the study reported in the previous chapter) at the University of Reading. After consenting to the MRI study, they were further invited to take part in an emotional diary task at home which they would complete in between the first and second session of the main MRI study. Participants from the MRI study who consented to the take part in the diary task included 40 older adults (21 females; age range: 50-87; *M*age = 67.43, SD = 9.14) and 22 younger adults (17 females; age range: 18-

21; *M*age = 19.32, SD = 1.21). Of these participants, in order to remove any possible cases of dementia, a further three older adults were also excluded from the analysis as they failed to reach the Mini Mental State Examination (MMSE) cut-off score of 26/30 (Folstein, Folstein, & McHugh, 1975; see Appendices 5.7.4 for all analyses including these participants). In addition, those with less than 2 SDs below the mean number of completed surveys were excluded from the main analyses. This included three older adults and one younger adult all of whom had less than 5 diary entries in total. In addition, three participants did not complete the full future-time perspective scale meaning that their data could not be used in the models. Therefore, the final analysis included 31 older adults (17 females; Mage = 64.71, SD = 7.80) and 21 younger adults (16 females; Mage = 19.33, SD = 1.24). The mean number of responses from the remaining participants was 17.84 entries (range = 9-22, SD = 2.72) for older adults and 13.67 entries (range = 6-19, SD = 4.59) for younger adults. Post-hoc sensitivity analysis using GPower (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that our sample size would provide 80% power to detect an interaction between future time perspective and age group for our diary data with a medium effect size of f^2 = .19 and .21 for our MRI data.

For the fMRI analysis, a total of six participants with maximum framewise displacement greater than 3mm were also excluded from the analysis (4 older adults and 2 younger adults). Therefore the final number of participants included 27 older adults (16 females; Mage = 63.89, SD = 7.51) and 19 younger adults (14 females; Mage = 19.32, SD = 1.20). The mean number of responses from the remaining participants was 17.88 entries (range = 13-20, SD = 2.15) for older adults and 13.68 entries (range = 6-19, SD = 4.80) for younger adults. This sample size in older adults would give us 85% statistical power to detect a strong correlation (*r* = .5).

5.3.2 Procedure

The procedures of Session 1 (day 1 of the diary study) are reported in Chapter 4 including the consent process and the scanning procedures (see Figure 4.1 in previous chapter and Figure 5.1 reported in this chapter).

Experience Sampling. The iPod touch was given to participants at the end of Session 1. It was programmed to signal an alarm three times per day between the hours of 9am and 10pm on seven consecutive days (starting the day of Session 1 and finishing the day before returning for Session 2). Two timing schedules were created with different pre-programmed alarm times so that the timings of the scheduled alarms could be counterbalanced across participants. The morning and afternoon alarms were set between 9am and 4:30pm and the evening alarm was scheduled daily for 8pm. For the morning and afternoon alarms, each timing schedule included 14 different time intervals (one for the morning and one for the afternoon for each day) during which a random beep could be generated. After each beep, participants were asked if they could take part in the survey or if they wanted to delay it. If participants began the survey, their state emotions were assessed (see Appendix 1; Table A1 in for a full list of questions). If the participant did not respond after the initial alarm, they were prompted a further five times (each after a 20-minute interval) at which point the application would time out until the next scheduled time interval. Each non-response was recorded as a missed entry. The data were stored locally within the iPod touch and were then uploaded to a secure server once returned back to the experimenter.

5.3.3 FMRI data acquisition and preprocessing

Details on data acquisition and preprocessing are also reported in Chapter 4 (see 4.3.7.1 General activation analysis).

General Linear Models (GLMs). In order to examine the changes in mean BOLD responses, GLMs were carried out for each run. The models included three EVs: positive, negative and neutral and modelled the following 3 contrasts: 1) positive > negative, 2) positive > neutral and 3) negative > neutral. As previously reported in Chapter 4, six motion estimate covariates and motion outliers (defined as outliers based on the 75th percentile + 1.5 times the Interquartile range) that were extracted using FSL's motion outliers tool (FSL v.6.0, FMRIB's Software Library, https://fsl.fmrib.ox.ac.uk/fsl/; Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012; Smith et al., 2004) were also included in the model to remove any brain activity or movement that was unrelated to the task.

Regions of Interest. We defined a priori regions of interest (ROIs), including the ventro-medial prefrontal cortex (vmPFC; see Figure 5.2A), the pregenual anterior cingulate cortex (pgACC; see Figure 5.2A) and the amygdala (see Figure 5.2B; see previous chapter for additional information on how these ROIs were defined). Here, we concentrated on the positive > negative contrast for each of our ROIs since stronger activation to positive over

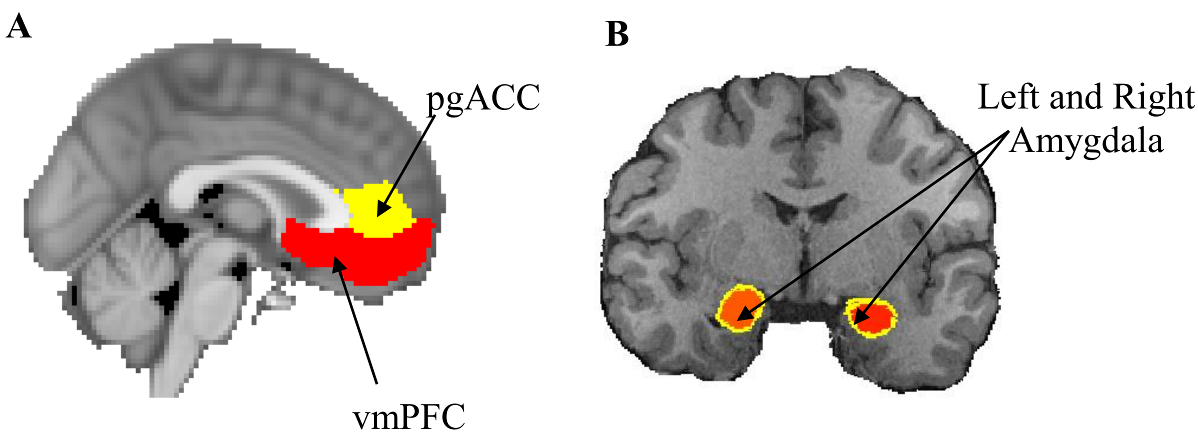

Figure 5.2 Regions of interest for A) the pgACC and vmPFC and B) the left and right amygdala.

negative stimuli in the vmPFC and amygdala has been considered as a manifestation of the positivity effect (e.g. Leclerc & Kensinger, 2008, 2010). In order to account for multiple comparisons, we applied a false discovery rate correction based on the number of ROIs (n = 4).

5.3.4 Measures

Daily Diary Questionnaire

In order to assess emotional experience sampling in younger and older adults, a series of emotion-related questions were administered over the one week period via the iPod touch. The same 60 items were presented to the participants each time (see Appendix 1; Table A1 for questions relating to this chapter).

Future Time Perspective. The Future Time Perspective Scale (FTP; Carstensen & Lang, 1996) comprises of 10 items that assess perceived limitations of time. The items assess an individual's beliefs about their future life with regards to opportunities such as "My future is filled with possibilities" and to limitations such as "I have the sense that time is running out". Each question was assessed on a 7-point Likert scale ranging from "very untrue" to "very true". The scores for the items that are negatively phrased were reverse scored and were then averaged so that higher scores represented a more expansive future time perspective. Internal consistency for future time perspective was $\alpha = .95$ for the older adults and $\alpha = .94$ for the younger adults. Three older adults who took part in an earlier version of the survey do not have complete future time perspective scale data and are therefore not included in any analyses using future time perspective.

Overall Mood. Participants were also asked how positive or negative they currently felt using a 7-point Likert scale ranging from 1 (very negative) to 7 (very positive).

Positive and Negative Emotion. Participants were asked to rate how intensely they currently felt 21 different emotions using a 7-point Likert scale ranging from 1 (not at all) to 7 (extremely). The emotions included the eight positive emotions (happiness, joy, contentment, excitement, pride, accomplishment, interest and amusement) and 11 negative emotions (anger, sadness, fear, disgust, guilt, embarrassment, shame, anxiety, irritation, frustration, and boredom) reported in Carstensen et al. (2011) with the addition of three extra positive emotions (pride, calm and curious; see Table 1 for mean intensity scores for each emotion). The following eight items were completed by all participants: *happiness, pride, calmness* and *curiosity, sadness, anxiousness, frustration* and *boredom*. For other purposes of the study, 52 participants (31 older adults and 21 younger adults) completed the full set of 21 items but these will not be reported in this chapter. Since previous research has found differences in younger and older adults in terms of the frequency and intensity of experienced emotions such as a reduction in the frequency of negative emotions (Carstensen et al., 2011) and greater reported positive intensity (Charles & Piazza, 2007), we examined both.

Positive and Negative Frequency. A frequency score of '1' was given to each emotion rating that was rated higher than '1' by the participant since a '1' indicated 'not at all'. In other words, when the participant reported experiencing an emotion by rating it 2 or higher on the Likert scale, it was given a frequency score of 1 (Carstensen et al., 2011). Average positive and negative emotion frequency scores were then calculated by averaging the frequency scores of happiness, pride, calmness and curiosity for positive emotion and sadness, anxiousness and frustration for negative emotion.

Positive and Negative Intensity. Average positive and negative emotion intensity scores were calculated by averaging the ratings of *happiness*, *pride*, *calmness* and *curiosity* for positive emotion (α values >.70 for each group), and *sadness, anxiousness* and *frustration* for negative emotion (α values >.69 for each group).

Perceived Stress. Feelings of stress were obtained using one item *"How strongly are you currently stressed?"*

Remaining questions. The remaining questions related to emotion prediction, social interaction, exercise and smoking behaviour, caffeine consumption and behaviour during the survey. They also included two questions relating to choice (S. Williams, 1998) and two questions relating to mind-wandering (Killingsworth & Gilbert, 2010).

5.3.5 Data Analysis

Our primary analysis concerned the relationship between the two groups (older adults vs. younger adults), future time perspective and the measures of emotional well-being such as the frequency and intensity of positive and negative emotions, overall mood and perceived stress. Firstly, a linear mixed-effects model was carried out in RStudio (v. 1.1.463) using the *lmer* function within the *lme4* package (v. 1.1-21; Bates, Mächler, Bolker, & Walker, 2015) in order to examine group differences in ratings of future time perspective. Subsequently, separate linear mixed-effects models were carried out in order to examine the relationship between age, future time perspective and emotional well-being outcomes. Dummy coding was used to create a group variable that was included in each of the models as a fixed effect (younger adults = 0; older adults = 1). Future time perspective was group mean centred prior to performing the analyses and was included in each model as a fixed and random effect. Our analysis also concerned the relationship between the two groups (older adults vs. younger adults), future time perspective and the positivity score in memory. A separate linear model was carried out using the *lm* function within the *stats* (v. 3.5.1; Chambers, 1992; Wilkinson & Rogers, 1973) to examine whether future time perspective and age group predicted the positivity score in memory.

ROI analysis

Separate multiple linear regressions were carried out to investigate whether average values of future time perspective and age group predicted average activation for the positive > negative contrast. For all subsequent ROI analyses, we ran additional models to control for the effects of age. We report corrected *p* values i.e. the *p* values after applying a false discovery rate correction based on the number of ROIs ($n = 4$).

Correlations. Since Pearson's correlation is not a robust measure of the associations between two variables in the presence of outliers (Wilcox, 2017) we therefore used Mair and Wilcox's percentage bend correlation: *pb* from the "WRS2" R package (Mair & Wilcox, 2020). It is a robust measure of the linear association between two separate variables but unlike Pearson's correlation, it is more robust to deviations within the data. For all analyses, we also ran separate models after controlling for the effects of chronological age to determine whether future time perspective was a stronger predictor of better emotional well-being than chronological age.

Table 5.1

Average intensity ratings for positive and negative emotions for younger and older adults.

Positive Emotions	**Young**		**Old**		*Negative Emotions*	**Young**		**Old**	
	M	SD	*M*	SD		M	*SD*	M	SD
Happy	3.02	0.97	3.49	1.04	Sad	0.93	0.98	0.36	0.84
Pride	1.57	1.29	2.20	1.49	Anxious	1.22	1.25	0.35	0.75
Calm	2.57	1.14	3.20	1.25	Frustrated	1.19	1.22	0.61	1.01
					Bored	1.53	1.32	0.35	0.75

Memory positivity score. As previously mentioned in Chapter 4, a memory positivity score (corrected recognition scores of negative images subtracted from the corrected recognition scores of positive images) was obtained allowing us to examine whether there was a greater benefit for positive versus negative images in memory for older adults compared to younger ones.

5.4 Results

5.4.1 Future time perspective

A linear mixed effects model examining whether younger and older adults differed in average ratings of future time perspective confirmed that older adults rated their future time perspective as more limited (*M* = 3.91, SD = 1.28) compared to younger adults (*M* = 4.58, SD = .99), β= -.67, *t* = -2.02, *p* = .049 (see Figure 5.3).

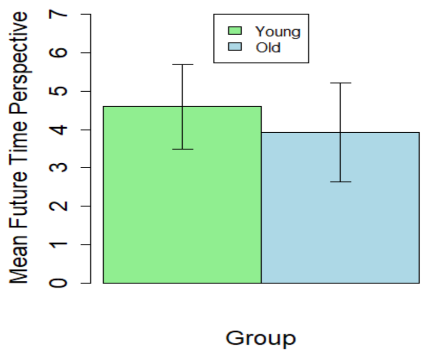

Figure 5.3. Mean ratings of future time perspective for younger and older adults. Error bars represent standard error.

5.4.2 Emotional Well-being

Is there a difference between younger and older adults in their daily experience of positive and negative emotion? Across the linear mixed-effects models of overall mood, perceived stress, frequency of negative emotion, intensity of positive and negative emotion, we found significant main effects of group; overall mood: β= 0.51, *t* = 2.98, *p* = .004, 95% CI [0.17 – 0.85] (see Table 5.2; Figure 5.4A), perceived stress: β= -1.57, *t* = -6.84, *p* <.001, 95% CI [-2.02 – -1.12] (see Table 5.2; Figure 5.4B), frequency of negative emotion: β= -.35, *t* = -5.53, *p* <.001, 95% CI [-0.48 – -0.23] (see Table 5.2; Figure 5.4C), intensity of negative emotion: β= -.68, *t* = -5.28, *p* <.001. 95% CI [-0.93 – -0.43] (see Table 5.2; Figure 5.4D) and intensity of positive emotion: β= .45, *t* = 2.14, *p* = .04. 95% CI [0.04 – 0.87] (see Table 5.2; Figure 5.4F). These results suggest that older adults, compared to younger adults, reported significantly higher ratings of overall mood, intensity of positive emotion and significantly lower ratings of perceived stress and frequency and intensity of negative emotion. There were no significant main effects of group for the frequency of positive emotion: β= .03, t = .57, p =.57. 95% CI [-0.06 – 0.11] (see Table 5.2; Figure 5.4E).

Furthermore, we also found significant main effects of future time perspective for overall mood: β= .44 t = 2.57, p = .01. 95% CI [0.11 – 0.78] (see Table 5.2; Figure 5.4A), perceived stress: β= -.86, t = -3.64 p <.001. 95% CI [-1.32 – -0.40] (see Table 5.2; Figure 5.4B), frequency of negative emotion: β= -.13, t = -2.22, p = .03. 95% CI [-0.24 – -0.01] (see Table 5.2; Figure 5.4C), intensity of negative emotion: β= -.56, t = -4.10, p < .001. 95% CI [-0.82 – -0.29] (see Table 5.2; Figure 5.4D), frequency of positive emotion: β= .07, t = 2.68, p =.01. 95% CI [0.02 – 0.12] (see Table 2; Figure 5.4E) and intensity of positive emotion: β= .55, t = 5.02, p = < .001. 95% CI [0.33 – 0.76] (see Table 5.2; Figure 5.4F). However, there were no group by future time perspective interactions (see Table 5.2). These results indicate that having a more expansive future time perspective, irrespective of age group, was associated with higher levels of overall mood and more intense positive emotions. Meanwhile, having a limited future time perspective was associated with greater levels of stress and the frequency and intensity of negative emotion.

Table 5.2

Mixed effects models examining the effects of age group and future time perspective on emotional wellbeing measures.

Fixed Effects									
	Overall Mood			Stress			Frequency of Negative Emotion		
Beta	*Estimates*	*95% CI*	*p*	*Estimates*	*95% CI*	*p*	*Estimates*	*95% CI*	*p*
Intercept	3.25	2.99 – 3.51	**<0.001**	2.55	2.20 – 2.90	**<0.001**	0.63	0.53 – 0.73	**<0.001**
Age Group	0.51	0.17 – 0.85	**0.003**	-1.57	-2.02 – -1.12	**<0.001**	-0.35	-0.48 – -0.23	**<0.001**
Future Time Perspective	0.44	0.11 – 0.78	**0.01**	-0.86	-1.32 – -0.40	**<0.001**	-0.13	-0.24 – -0.01	**0.026**
Interaction	0.03	-0.42 – 0.48	0.905	0.26	-0.37 – 0.89	0.413	0	-0.16 – 0.15	0.989
Random Effects									
	Variance	*SD*	*Correlation*	*Variance*	*SD*	*Correlation*	*Variance*	*SD*	*Correlation*
Participant (Intercept)	0.33	0.56	-	0.6	0.77	-	0.05	0.21	-
Future Time Perspective	0.34	0.58	-0.17	0.64	0.8	-0.55	0.03	0.17	-0.21
Model Fit									
Marginal R^2 / Conditional R^2	0.092 / 0.511			0.282 / 0.584			0.195 / 0.514		

cont.

	Intensity of Negative Emotion			Frequency of Positive Emotion			Intensity of Positive Emotion		
Beta	*Estimates*	*95% CI*	*p*	*Estimates*	*95% CI*	*p*	*Estimates*	*95% CI*	*p*
Intercept	1.15	0.95 – 1.34	**<0.001**	0.85	0.78 – 0.92	**<0.001**	2.14	1.82 – 2.47	**<0.001**
Age Group	-0.68	-0.93 – -0.43	**<0.001**	0.03	-0.06 – 0.11	**0.568**	0.45	0.04 – 0.87	**0.032**
Future Time Perspective	-0.56	-0.82 – -0.29	**<0.001**	0.07	0.02 – 0.12	**0.007**	0.55	0.33 – 0.76	**<0.001**
Interaction	0.19	-0.18 – 0.56	0.309	0	-0.06 – 0.07	0.907	0.01	-0.29 – 0.30	0.951

Random Effects

	Variance	*SD*	*Correlation*	*Variance*	*SD*	*Correlation*	*Variance*	*SD*	*Correlation*
Participant (Intercept)	0.18	0.42	-	0.02	0.15	-	0.54	0.74	-
Future Time Perspective	0.19	0.43	-0.74	0.004	0.07	-0.39	0.09	0.3	0.09

Model Fit

Marginal R^2 / Conditional R^2	0.181 / 0.456	0.017 / 0.590	0.089 / 0.684

Key: p-values for fixed effects calculated using Satterthwaites approximations. Confidence Intervals have been calculated using the standard error.

Model equation: Emotional well-being measure ~ (1 + Future Time Perspective | Participant) + Group x Future Time Perspective

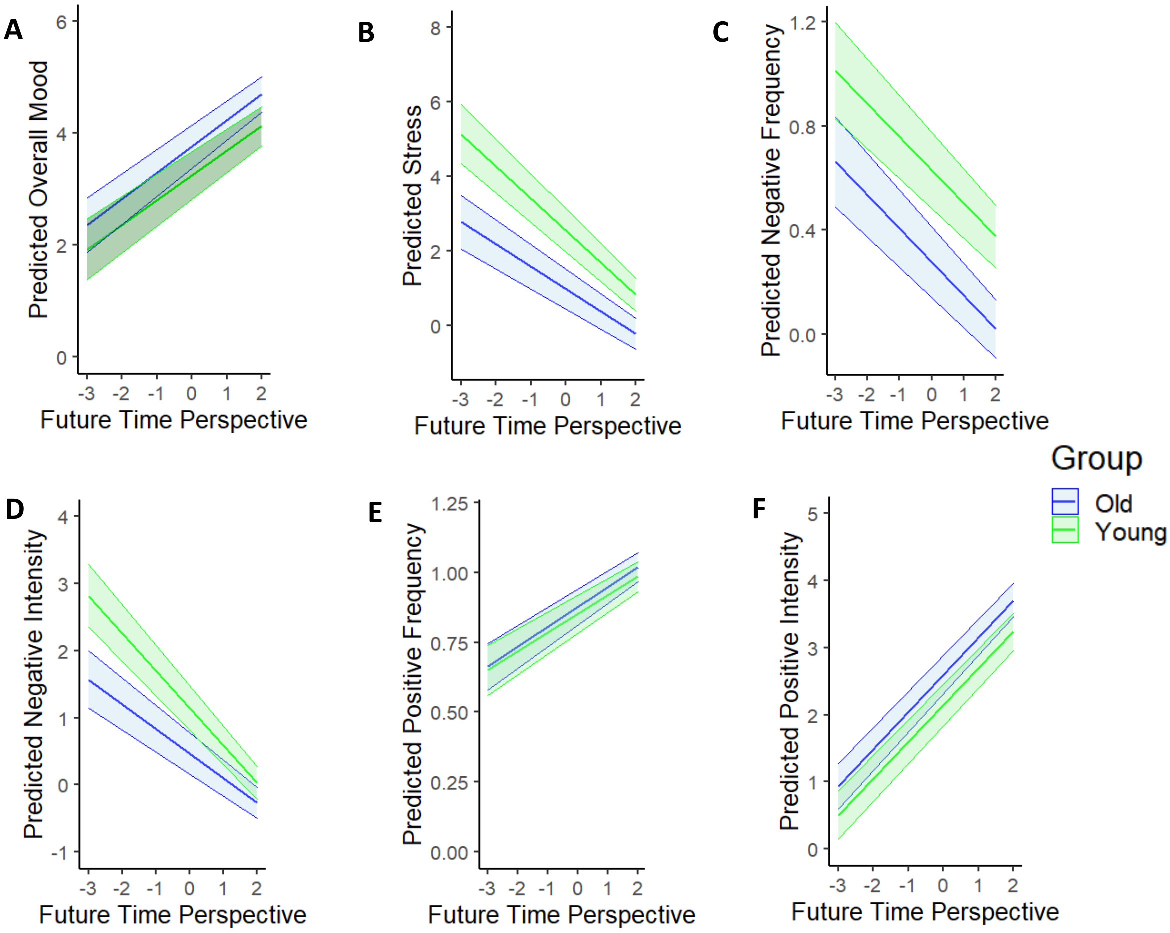

Figure 5.4. Model estimated marginal means for A) Overall Mood, B) Stress, C) Negative Frequency, D) Negative Intensity, E) Positive Frequency and F) Positive Intensity. Error bars represent standard errors.

5.4.3 The Positivity Effect

Does future time perspective predict the positivity effect in memory in younger and older adults? Here, a linear model including age group and future time perspective and an interaction between the two did not show a significant main effect of future time perspective, β= -0.03, *t* = -.5, *p* =.40, age group, β= 0.10, *t* = .62, *p* =.54 or interaction, β= -.01, *t* = -.*39*, *p* =.70 on the memory positivity score. When looking separately at the relationship between future time perspective and the memory positivity score among older adults, the correlation between future time perspective was not significant, p = .08, even after controlling for the effects of age, p =.05 (see Figure 5.5).

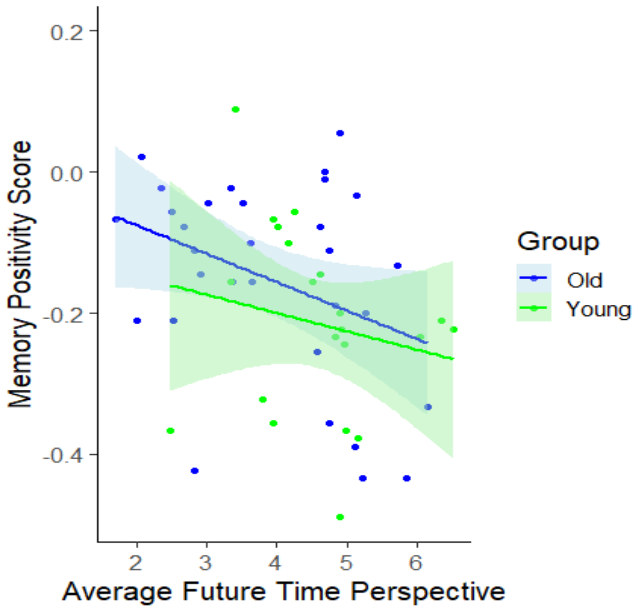

Figure 5.5. Relationship between future time perspective and memory positivity score for younger and older adults. Error bars represent standard deviation.

5.4.4 General pgACC and vmPFC Activation

The results of the regression revealed no significant main effects or interaction between age group and future time perspective for the positive > negative pgACC, corrected *ps* >.07 (see Table 5.3; Figure 5.6A) or the positive > negative vmPFC, corrected *ps* >.53 (see Table 5.3; Figure 5.6B).

5.4.5 General Left and Right Amygdala Activation

An outlier was detected in the data for the left and right amygdala (see Figure 5.6C and D) and was therefore removed from the subsequent analyses. The results of the regression for the left and right amygdala revealed a main effect of group: left amygdala activation, $\beta = 50.93$, $t = 3.54$, $p = .004$; right amygdala activation, $\beta = 47.73$, $t = 2.44$, $p =$ .04 and showed that older adults had higher levels of left and right amygdala activation to positive > negative pictures compared to younger adults. There was also a significant interaction between age group and future time perspective for the left amygdala, $\beta = -10.32$, $t = -3.22$, $p = .01$ (see Table 5.3; Figure 5.6C) but not for the right amygdala, $p = .051$ (see Table 5.3; Figure 5.6D). Follow-up analyses for the left amygdala were then conducted separately for each age group which revealed a significant percentage bend correlation within older adults between future time perspective and the positive > negative left amygdala activation, $r = -.52$, $p = .006$. In other words, among older adults, there was a negative correlation between ratings of future time perspective and positive > negative left amygdala activation. These results remained significant even after the effects of age had been controlled for, $r = -.42$, $p = .03$ and suggest that older adults with a less expansive future time perspective show greater amygdala activation to positive > negative images. In other words, those who perceive future time as limited exhibit a neural pattern of the positivity effect. The correlation between future time perspective and positive > negative left amygdala activation was not significant among younger adults, $r = .33$, $p = .18$

Supplementary analysis that included all participants (including older adults who were initially excluded based on MMSE scores) were consistent with the results reported above (see Appendix 2; Tables A2-3 and Figures A2-5).

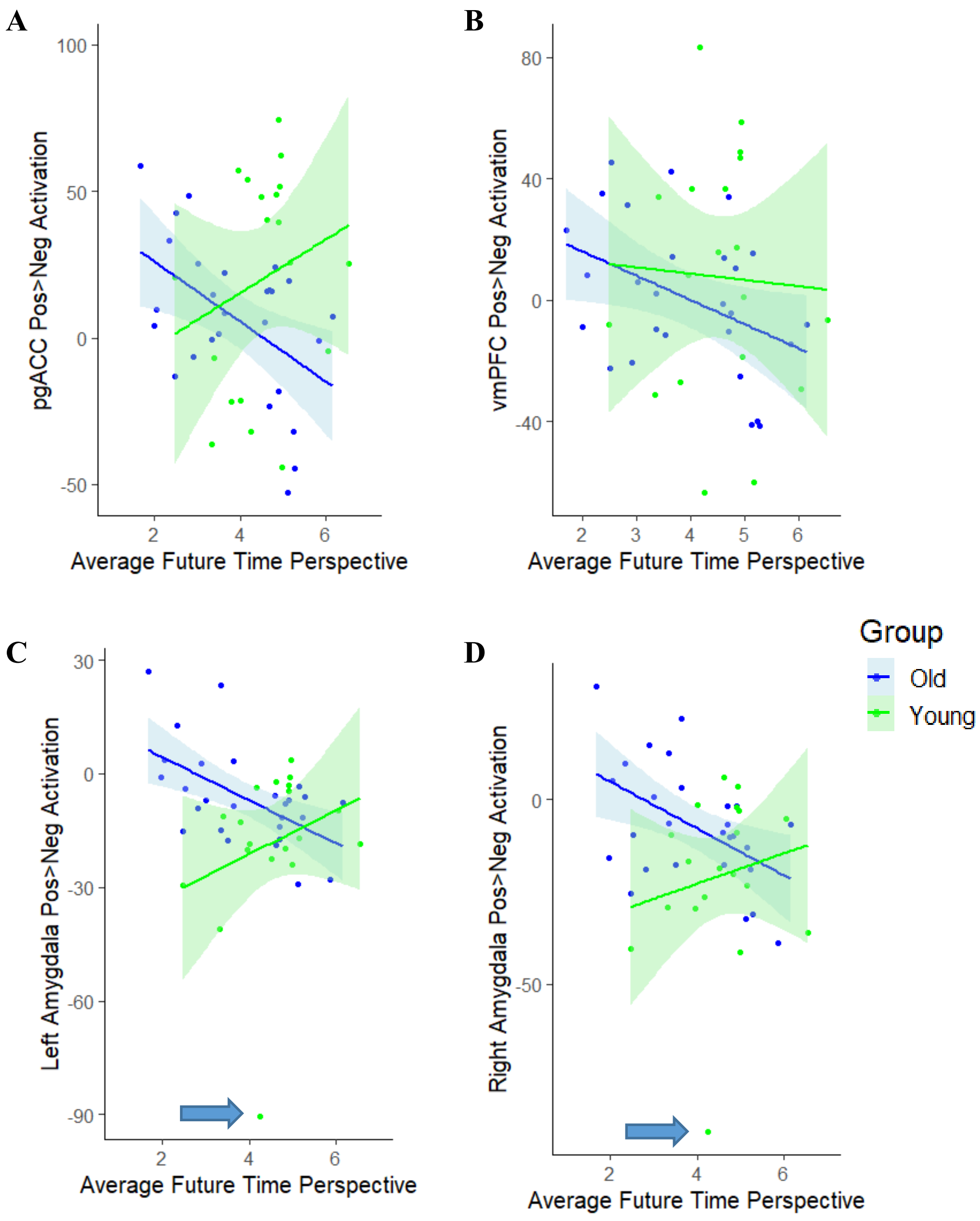

Figure 5.6. Relationship between future time perspective and positive > negative activity for A) pgACC, B) vmPFC, C) left amygdala and D) right amygdala for younger and older adults. Error bars represent standard errors. Arrows indicate outlier that was removed from analysis.

5.5 Discussion

The present study examined the role of future time perspective in emotional processing across neural, behavioural and subjective well-being measures in both younger and older adults to evaluate the predictions of the SST. More specifically, we firstly aimed to replicate previous findings of the age-related differences frequently seen in emotional well-being, expecting to find a better emotional well-being profile among older adults. Recent research however suggests that a less expansive future time perspective is associated with poorer emotional well-being, meanwhile other research suggests that a less expansive future time perspective is associated with measures of the positivity effect. Therefore, we tested both of these predictions using behavioural, neural and subjective well-being measures. Our expectation was that while a more limited future time perspective may be associated with poorer emotional well-being in younger and older adults, it would be associated with greater positivity seen in memory. We further examined the neural activation of the amygdala and the medial PFC (including the vmPFC and pgACC) expecting that a less expansive future time perspective would predict greater activation to positive > negative images, which would support SST's predictions about older adults possibly using emotion regulation strategies to maximize positive affect when viewing emotional images.

We successfully replicated previous findings which show that older adults demonstrate better emotional well-being compared to younger adults. More specifically, older adults reported significantly lower feelings of stress and the frequency and intensity of negative emotion but significantly higher ratings of overall mood and the intensity of positive emotion. Interestingly, there were no significant differences in the frequency of positive emotion between younger and older adults (Carstensen et al., 2000) yet older adults reported greater intensity of positive emotion. This is in contrast to previous findings on negative emotion in which older adults are found to experience negative emotions less often but just as intensely as younger adults (Carstensen et al., 2000, 2011). However, other work has found that older adults do report more intense emotions than younger adults (Kunzmann, Kupperbusch, & Levenson, 2005) particularly when reporting about emotional intensity with family members (Charles & Piazza, 2007). Importantly, however, when examining the role of future time perspective on these subjective well-being measures, we did not find support for the SST. Instead, we found that a more expansive future time perspective was associated with better emotional well-being for both younger and older adults; a finding which is more consistent with recent research (Bohn, Kwong See & Fung, 2016; Demiray & Bluck, 2013; Grühn, Sharifian & Chu, 2016; Kotter-Grühn & Smith, 2011) than the predictions made by the SST. In addition, we previously reported in Chapter 4 that older adults demonstrated a preference for positive over negative images, however, our results here indicate that a more limited future time perspective was not associated with greater positivity in memory. Therefore, in summary, across our subjective well-being and behavioural measures, we did not find evidence to support the predictions of the SST; that a more limited future time perspective is responsible for age-related differences in subjective well-being and memory.

However, when examining the effects of age group and future time perspective on neural activation to positive > negative images, we did find a significant age group by future time perspective interaction for the left amygdala. Our follow-up analyses among older adults revealed that increased activation within the left amygdala to positive > negative images was negatively correlated with future time perspective. To clarify, older adults who considered their time left in their lives to be less expansive, exhibited a neural pattern of the positivity effect in the left amygdala i.e. increased activation to positive > negative images. This is partly consistent with previous work which has found greater activation in the amygdala to positive valence among older adults (e.g. Kehoe, Toomey, Balsters, & Bokde, 2013; Leclerc & Kensinger, 2010; Mather et al., 2004) and possibly reflects the successful engagement of emotion regulation strategies to reduce feelings of negative affect. It is important to clarify however that while we found increased amygdala activation to positive > negative images, this was driven by reduced amygdala responses to negative stimuli and not increased amygdala responses to positive stimuli (see Appendix 4 for follow-up analyses). As such, our results support the idea of the positivity effect being a reduced negativity bias.

Moreover, it is important to acknowledge that we did not find evidence of age-related differences in the prefrontal regions that are typically associated with emotion regulation such as the vmPFC and pgACC which would have strengthened this claim. Therefore, it is difficult for us to know whether the reduction in left amygdala activity to negative images among older adults is the result of successful emotion regulation or whether it reflects an attenuated response to negative stimuli due to neural degeneration within the amygdala (Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011). Nevertheless, our results for the left amygdala remained significant even after chronological age had been controlled for suggesting that perception of time left in our life, rather than chronological age, is associated with the positivity effect in the neural activation of the amygdala. Unlike our previous results, these results *do* provide support for the SST and possibly reflect one pathway through which future time perspective can lead older adults to experience increased positive affect.

Although our behavioural and subjective well-being findings may seem contradictory to our neural ones, we believe that our findings could reflect different pathways through which future time perspective can influence emotional processing in older adults as has previously been found (Li & Siu, 2021). Previously, measures of future time perspective have been found to have a significant negative indirect effects on subjective measures of life satisfaction and depression, mediated by life goal preference, while the direct effects on subjective well-being were in the opposite direction (Li & Siu, 2021). Here, although we did not measure goal prioritization changes and were unable to test the effects of potential mediators since our neural data was collected before our diary data, it is possible that within the laboratory based setting, a less expansive future time perspective when viewing emotional stimuli, encouraged older adults to engage in emotion regulation strategies in an attempt to maintain feelings of positivity or reduce negativity. As a result, older adults with a less expansive future time perspective exhibited increased amygdala activity to positive over negative images. Therefore, taken together, our results and that of Li and Siu (2021) reaffirm the importance of considering the role of future time perspective in emotional processing among older adults and highlight the importance of examining both the direct and indirect effects (see Figure 5.7).

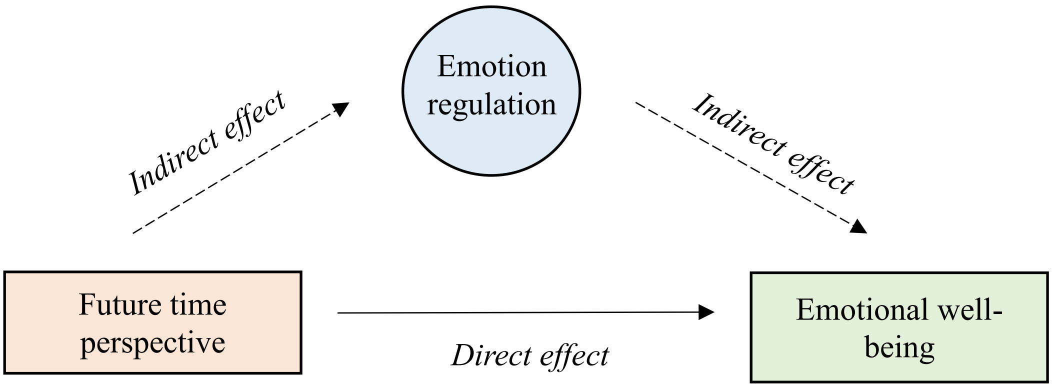

Figure 5.7. Theoretical model of direct versus indirect effects of future time perspective on emotional well-being.

It is also important to acknowledge the possible differences between our measures which may have contributed to these opposing effects. For example, if older adults do rely upon emotion regulation efforts to maximize feelings of positive affect in both daily life and during emotional processing within the laboratory, it is likely that different regulation methods were utilised. Importantly, research has shown that older adults may benefit more from antecedent emotion regulation strategies (Urry & Gross, 2010) which are considered to be more effective since they are implemented before an individual experiences the peak of emotion (Gross, 1998). When used in daily life, these types of strategies allow older adults to carefully select their social networks (English & Carstensen, 2014; Rook & Charles, 2017) and what activities they choose to engage in, so that negative outcomes can be avoided altogether (Luong, Charles, & Fingerman, 2011). However, these types of emotion regulation strategies that are implemented spontaneously in daily life are unlikely to be the default strategies spontaneously used during emotional processing within laboratory-based settings, where negative images for example, cannot be avoided. Therefore, it might be the case that effects of future time perspective are dependent upon the types of emotion regulation strategies older adults implement i.e. more cognitively demanding strategies like reappraisal (Scheibe, Sheppes, & Staudinger, 2015) versus less-demanding strategies like situation selection. Furthermore, just by simply recruiting the brain areas responsible for emotion regulation during emotional processing does not necessarily guarantee behavioural changes (Grühn et al., 2016) that could reflect better emotional well-being.

Other factors that have been identified as important to consider when measuring future time perspective concern an individuals' health (Grühn et al., 2016). Since previous research found that individuals suffering from moderate levels of Alzheimer's disease viewed their time as more similar to younger older adults than to older adults of a similar chronological age (Bohn et al., 2016), we excluded participants who failed to meet the MMSE cut-off score from our analysis. This allowed us to be more confident that the perception of time among our older adults was not distorted through having a cognitive impairment. That being said, it is also possible that people may use their physical health status when considering their future time perspective. As such, those experiencing ill-health may be more likely to consider their time as less expansive. Here, we did obtain daily measures of perceived health among younger and older adults, however our findings suggest that despite older adults reporting greater levels of medication use and diagnosed illnesses, they rated their health significantly better than younger adults (see supplementary material).

This therefore made it difficult to incorporate this measure into our analysis since it is likely that the two age groups answered this question differently. It could be that the younger participants were more likely to incorporate their mental health when answering this question. This theory is supported by our emotional well-being data as well as our mood questionnaire data obtained on Day 1 of the experiment (previously reported in Chapter 4), in which younger adults experienced significantly less positive affect but greater levels of negative affect and depressive symptoms compared to older adults.

While our findings are unique in that we have adopted a multifaceted approach to understanding the role of future time perspective across behavioural, neural and subjective well-being measures, there are several limitations that should be highlighted. Firstly, although our method of experience sampling provides us with richer data that is unbiased by retrospective reporting, the older adults engaged more in this aspect of the study, providing, on average, more responses than younger adults did. Therefore, group-level differences in well-being may be due to an imbalance in the recorded data between younger and older adults (see Appendix 3 for supplementary analysis on emotional well-being data when number of surveys is included in the models). In addition to this, our sample size, in comparison to other experience sampling studies (Brose, de Roover, Ceulemans, & Kuppens, 2015; Carstensen et al., 2000; Carstensen et al., 2011), is small and the duration of one week may not have been sufficient to evidence sufficient intra-individual variability in emotional well-being. It is also possible that since our experience sampling survey questions were always administered in the same order; that is, the positive and negative emotions first followed by the future time perspective scale, that ratings of future time perspective were primed. In other words, it is difficult to know if those who reported higher positive emotion and lower negative emotion were then more likely to consider their future life as more expansive. Future studies using similar approaches should therefore consider counterbalancing the order of assessed emotions and future time perspective measurements to account for this potential confound.

In terms of our participants, many of our older adults were significantly younger than what previous studies consider ‘old’ (Bohn et al., 2016; Hoppmann, Infurna, Ram, & Gerstorf, 2017; Kotter-Grühn & Smith, 2011). The reason for this was that during participant recruitment, older adults were more likely to have medical conditions that precluded them from being invited to the main study and taking part in the MRI scanning procedures. This means that we should be cautious when making direct comparisons between our study and those examining the effects of future time perspective among older old adults. In addition to this, research shows that people aged between 40 and 60 become more aware that their time is limited but equally accept that there is still enough time left to make plans suggesting that there is a greater balance between future opportunities and limitations (see Lachman, Teshale, & Agrigoroaei, 2015). Since many of our participants fall within this age range, it could be that the future time perspective scale is answered differently depending on chronological age. It also opens up the possibility that there could be differences in older adults self-perception of aging (Weiss & Lang, 2012). For example, younger older adults may not perceive themselves as their actual age and may relate more strongly to younger people which could have influenced future time perspective measures.

Finally, some researchers (e.g. Cate & John, 2007; Rohr, John, & Fung, 2017) suggest that Carstensen and Lang’s future time perspective scale is not a one dimensional construct. The scale includes questions relating to future opportunities as well as limitations and works on the assumption that those who view their time as more limited will be less focused on future opportunities. However, more recent work has questioned this assumption and found that an individual can consider their time to be limited and still consider future opportunities (Cate & John, 2007). Interestingly, when the future time perspective scale was separated into three components to include future time opportunities, extension and constraint, the authors found that higher levels of future opportunities and extension were associated with fewer present-focused goals which in turn were related to higher levels of depression and lower levels of life satisfaction (Li & Siu, 2021). Here however, we examined future time perspective as one construct in order to replicate previous findings and test the predictions of the SST but future research should consider whether future opportunities versus future limitations are similarly associated with subjective well-being measures.

In conclusion, the current study found that a more limited future time perspective was associated with poorer emotional well-being, was not associated with positivity effects in memory but did predict greater amygdala activity in older adults to positive > negative images. These results suggest that the SST should not be completely dismissed as a valid framework for helping to explain age-related differences in emotional processing. Instead, future research should consider the role of future time perspective across different contexts, including behavioural, neural and emotional well-being. In addition, future research should give more consideration to the direct and indirect role of future time perspective on emotional processing.

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5.7 Appendices

5.7.1 Appendix 1: Table of survey questions that were administered to participants in the study

Table A1

List of questions and corresponding scales and items relevant to the current analysis

Question	Scale / items
1) In general, how positive/negative do you currently feel?	***1 (very negative) - 7 (very positive)***
2) Please read each item and select the number corresponding to how intensely you feel that emotion at the moment.	***1 (not at all) - 7 (extremely)*** *Happy, pride, sad, anxious, frustrated, bored, calm, curious, joy, embarrassment, shame, contentment, amusement, anger, disgust, excitement, accomplishment, guilt, interest, fear, irritation*
3) How strongly are you currently stressed?	***1 (not at all) - 7 (extremely)***
4) Please read each item and answer the questions with "How true is this of you?" Select the appropriate number on the scale.	***1 (very true) - 7 (very untrue)*** *Most of my life lies ahead of me.* *There is plenty of time left in my life to make new plans.* *I feel like time left in my life is limited.* *Many opportunities await me in the future.* *I expect that I will set many new goals in the future.* *My future is filled with possibilities.* *My future seems infinite to me.* *I could do anything I want in the future.* *I have the sense time is running out.* *There are only limited possibilities in my future.* *As I get older, I begin to experience time as limited.*

5.7.1 Appendix 1: Supplementary analyses

A secondary aim of this chapter was to investigate the both the stability of affective experiences and the emotional complexity between younger and older adults. Previous research indicates that compared to younger adults, older adults exhibit more stable emotions. In other words, the within-person variability of positive and negative affect is smaller in older than in younger adults (Carstensen et al., 2011; Röcke, Li, & Smith, 2009). This increase in emotional stability is thought to contribute to their increased emotional well-being (Carstensen et al., 2011); the idea being that a more adaptive emotional response to events in daily life would be associated with less intense affective reactions (Grosse Rueschkamp, Kuppens, Riediger, Blanke, & Brose, 2020). For older adults then, one way in which they may maintain higher levels of emotional well-being could be through reducing their affective reactivity and maintaining a more stable emotional response (Röcke et al., 2009). Indeed, in a more recent meta-analysis, lower psychological well-being was associated with more variable and unstable emotions (Houben, Van Den Noortgate, & Kuppens, 2015).

On the other hand, older adults are also thought to experience more emotional complexity. Although it has several definitions, emotional complexity is more broadly thought to reflect the extent to which a person simultaneously experiences different emotions as well as the ability to differentiate their own emotions (Grühn, Lumley, Diehl, & Labouvie-Vief, 2013; Ong & Bergeman, 2004). A straightforward example is the co-occurrence of positive (e.g. happiness) and negative emotions (e.g. sadness) which may reflect more complex emotions such as “poignancy” (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000). More generally, greater emotional complexity is thought to reflect better adjustment (Carstensen et al., 2000) and is also associated with greater psychological resilience (Ong & Bergeman, 2004). More importantly, it is also thought to be related to emotion regulation. For example Hay and Diehl (2011) found that those individuals who reported more emotional complexity were able to move away from a highly negative affective state more quickly compared to those who reported lower emotional complexity suggesting that these individuals were able to regulate emotions more effectively.

As such, these two measures; emotional stability and complexity, could be important factors to consider when understanding the age-related differences frequently seen in emotional well-being. In the current study, we therefore examined emotional stability by examining fluctuations in emotional measures over time. One way to assess these fluctuations is by calculating the root mean square successive difference (RMSSD) which is a measure of trial-by-trial variability. A greater RMSSD value therefore reflects greater instability in positive and negative emotion (Carstensen et al., 2011). As for measuring emotional complexity, one way is to compute an intra-individual correlation between positive and negative affect over time. In this case, a correlation close to zero would indicate that positive and negative emotion are experienced more separately. Meanwhile a correlation that is closer to -1 would suggest that a person does not discriminate between the two but instead experiences them on a single, yet bipolar dimension.

5.7.1.1 Supplementary Measures

Health. Ratings of health were obtained using one item *"How do you feel about your overall health?"* using a scale from 1 (very bad) to 7 (very good).

Emotional Stability. Positive and negative emotion and overall mood stability scores were obtained by computing the root mean square successive difference (RMSSD) for positive emotion, negative emotion and overall mood separately. RMSSD is a measure of trial-by-trial variability and is used here as a time-series statistic that accounts for changes over time.

Affective Bipolarity. To measure whether positive and negative emotions were experienced independently or as bipolar opposites, a within-person correlation between positive and negative intensity and frequency was obtained.

5.7.1.2 Supplementary Data Analysis

Health. A linear mixed effects model examined the relationship between the two groups (older adults vs. younger adults), future time perspective and overall health.

Emotional Stability and Affective Bipolarity. Our analysis also concerned the relationship between the two groups (older adults vs. younger adults), future time perspective and the average measures of emotional stability (RMSSD of positive and negative emotion), affective bipolarity (the correlation between positive and negative emotion). Separate linear models were carried out using the *lm* function within the *stats* (v. 3.5.1; Chambers, 1992; Wilkinson & Rogers, 1973) to examine whether future time perspective and age group predicted emotional stability, and affective bipolarity.

5.7.1.3 Supplementary Results

Health. A linear mixed effects model examining whether younger and older adults differed in average ratings of health revealed that older adults rated their overall health better (M = 3.82, SD = 0.91) than younger adults did (M = 3.16, SD = .69), β= .63, t = 3.03, p = .004.

Emotional Well-being.

Is there a difference between younger and older adults in their emotional stability and affective bipolarity? Across the three models of emotional stability and the intensity and frequency of affective bipolarity, there were no main effects of group, future time perspective and no significant interactions (see Appendices Table 5.7.1).

Is there a difference between younger and older adults in their stability of positive and negative emotion and overall mood? For measures of stability for positive and negative emotion and overall mood, we did not find significant main effects of group, future time perspective or interactions in any of the models (see Appendices 5.7; Table A2; Figure A1).

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Table A2

General linear models examining the effects of age group and future time perspective on emotional stability

	RMSSD Overall Mood			**RMSSD of Positive Emotion**			**RMSSD of Negative Emotion**		
Beta	*Estimates*	*95% CI*	*p*	*Estimates*	*95% CI*	*p*	*Estimates*	*95% CI*	*p*
Intercept	0.68	-0.21 – 1.58	0.13	0.26	0.01 – 0.52	0.043	0.15	-0.20 – 0.51	0.383
Age Group	0.07	-0.95 – 1.10	0.883	-0.05	-0.34 – 0.24	0.726	0.13	-0.27 – 0.53	0.523
Future Time Perspective	0.09	-0.10 – 0.28	0.354	-0.02	-0.08 – 0.03	0.442	0.05	-0.03 – 0.12	0.219
Interaction	-0.1	-0.33 – 0.13	0.379	0	-0.06 – 0.07	0.94	-0.03	-0.12 – 0.06	0.448
Observations	52			52			52		
R2 / R2 adjusted	0.185 / 0.134			0.049 / -0.011			0.048 / -0.012		

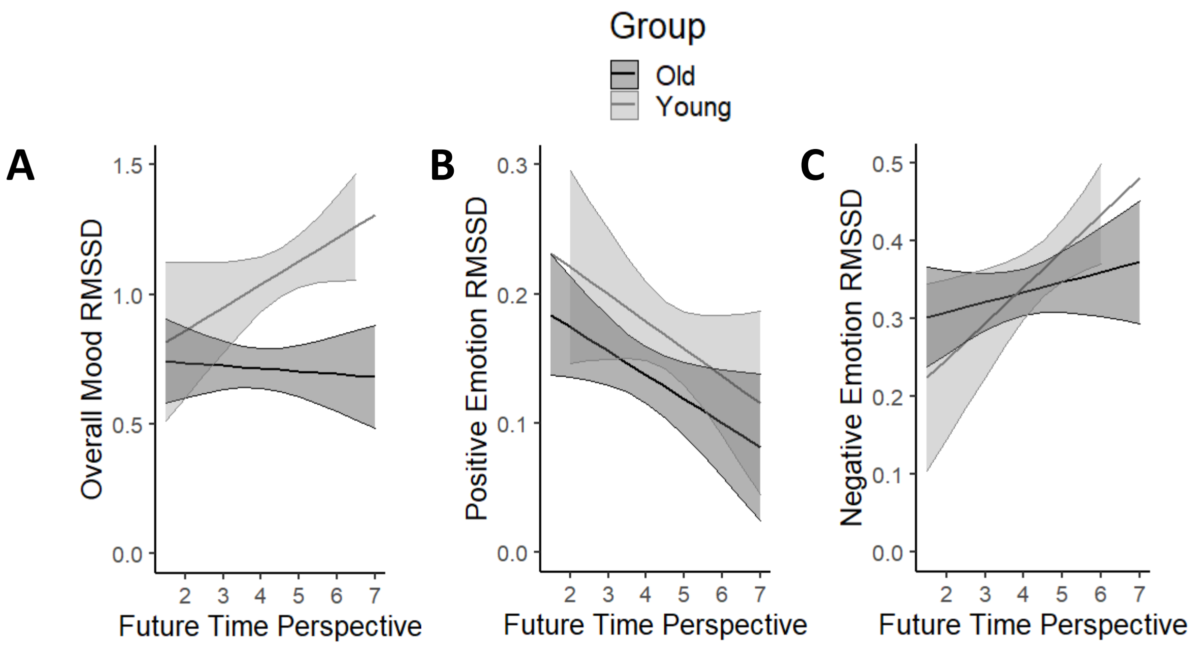

Figure A1. Model estimated marginal means for the root mean square successive difference (RMSSD) for A) overall mood, B) positive emotion and C) negative emotion. Error bars represent standard errors.

5.7.2 Appendix 2: Supplementary tables and figures for analysis including all participants

The following tables and figures include data from all participants including older adults who were previously excluded based on their MMSE score (less than 26/30). The participants included in the subsequent analysis include 37 older adults (20 females; Mage = 66.35, SD = 8.63) and 21 younger adults (16 females; Mage = 19.33, SD = 1.24). The mean number of responses from the remaining participants was 17.46 entries (range = 8-22, SD = 3.03) for older adults and 13.67 entries (range = 6-19, SD = 4.59) for younger adults. For the fMRI analysis, participants included 33 older adults (19 females; Mage = 65.88, SD = 8.64) and 19 younger adults (14 females; Mage = 19.32, SD = 1.20). The mean number of responses from the remaining participants was 17.45 entries (range = 8-20, SD = 2.68) for older adults and 13.68 entries (range = 6-19, SD = 4.80) for younger adults.

5.7.2.1 Figure of mean ratings for future time perspective for younger and older adults

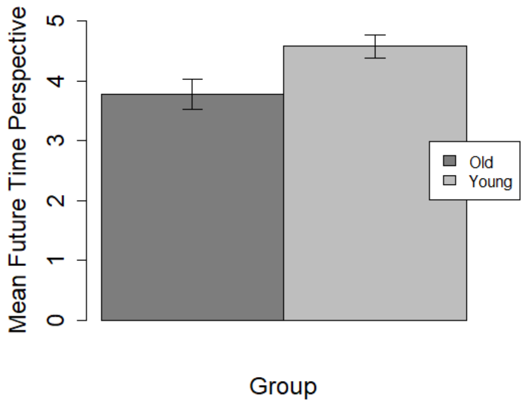

Figure A2. Mean ratings of future time perspective for younger and older adults. Error bars represent standard deviation.

5.7.2.2 Table of mixed effects models for positive and negative emotion for younger and older adults

Table A2

Mixed effects models examining the effects of age group and future time perspective on emotional well-being measures.

	Overall Mood			**Stress**			**Frequency of Negative Emotion**		
Beta	*β*	*95% CI*	*p*	*β*	*95% CI*	*p*	*β*	*95% CI*	*p*
Intercept	3.25	2.99 – 3.51	**<0.001**	2.55	2.21 – 2.90	**<0.001**	0.63	0.53 – 0.73	**<0.001**
Age Group	0.55	0.22 – 0.89	**0.001**	-1.59	-2.03 – -1.16	**<0.001**	-0.36	-0.48 – -0.24	**<0.001**
Future Time Perspective	0.44	0.11 – 0.77	**0.009**	-0.86	-1.32 – -0.40	**<0.001**	-0.13	-0.24 – -0.02	**0.023**
Interaction	0.02	-0.41 – 0.46	0.914	0.3	-0.31 – 0.91	0.339	0.01	-0.14 – 0.15	0.937
N	55			55			55		
Observations	879			879			879		
Marginal R^2 / Conditional R^2	0.101 / 0.527			0.285 / 0.582			0.201 / 0.523		
	Intensity of Negative Emotion			**Frequency of Positive Emotion**			**Intensity of Positive Emotion**		
Beta	*β*	*95% CI*	*p*	*β*	*95% CI*	*p*	*β*	*95% CI*	*p*
Intercept	1.15	0.95 – 1.34	**<0.001**	0.85	0.79 – 0.92	**<0.001**	2.14	1.82 – 2.47	**<0.001**
Age Group	-0.69	-0.94 – -0.45	**<0.001**	0.02	-0.06 – 0.11	**0.597**	0.43	0.02 – 0.84	**0.038**
Future Time Perspective	-0.56	-0.82 – -0.30	**<0.001**	0.07	0.02 – 0.12	**0.01**	0.54	0.33 – 0.76	**<0.001**
Interaction	0.22	-0.13 – 0.57	0.22	0.01	-0.06 – 0.08	0.739	0.02	-0.27 – 0.32	0.873
N	55			55			55		
Observations	879			879			879		
Marginal R^2 / Conditional R^2	0.186 / 0.463			0.018 / 0.577			0.083 / 0.682		

5.7.2.3 Figure of mean ratings for future time perspective for younger and older adults

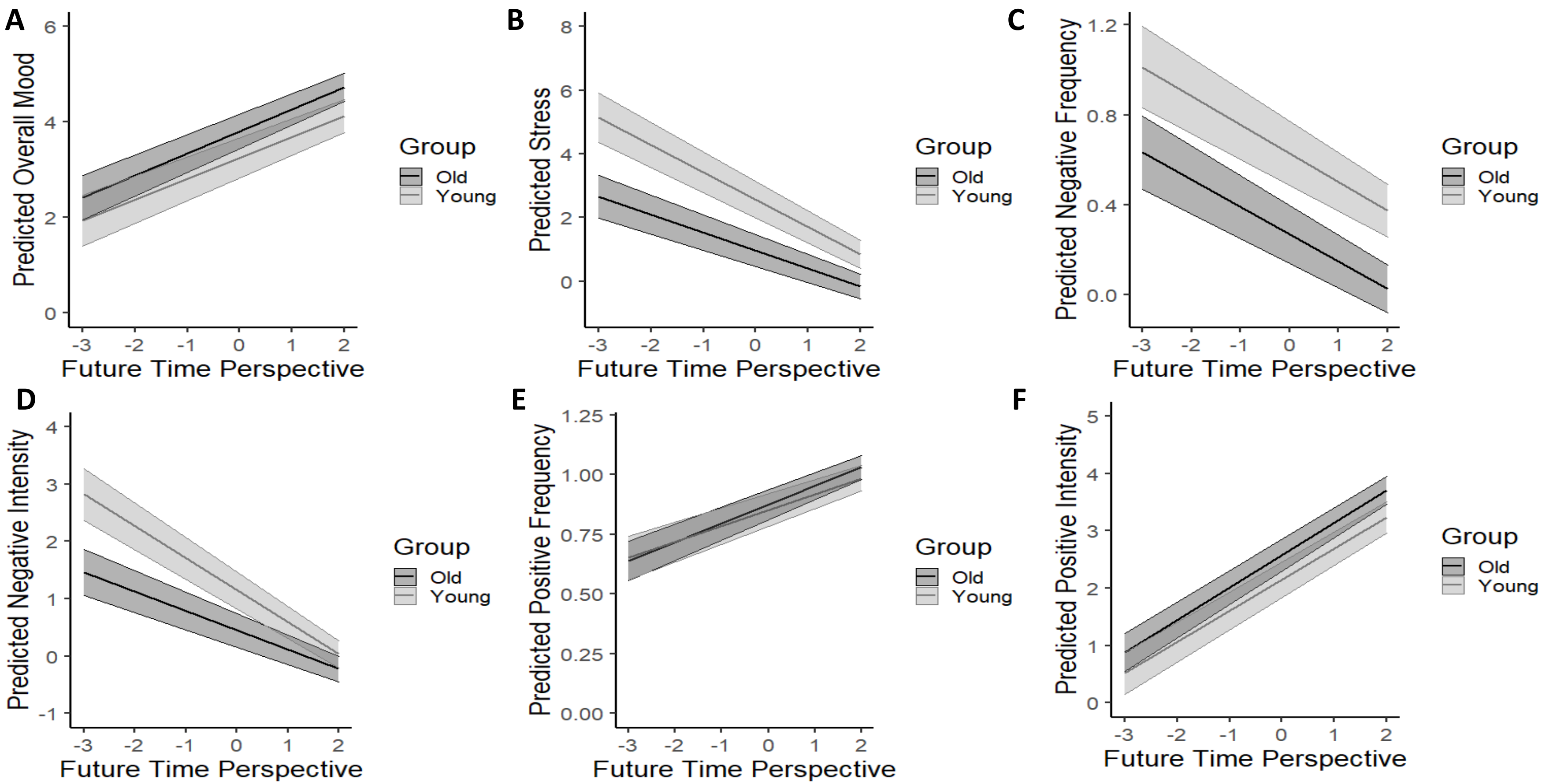

Figure A3. Model estimated marginal means for A) Overall Mood, B) Stress, C) Negative Frequency, D) Negative Intensity, E) Positive Frequency and F) Positive Intensity. Error bars represent standard errors.

5.7.2.4 Figure of relationship between future time perspective and the memory positivity score for younger and older adults

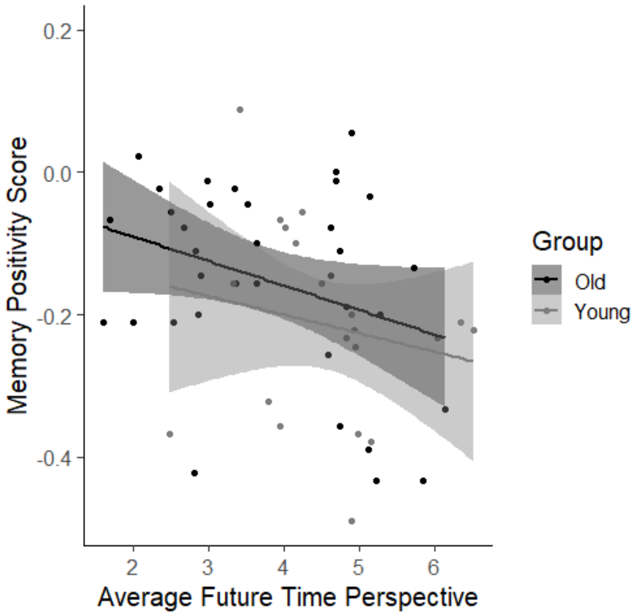

Figure A4. Relationship between future time perspective and memory positivity score for younger and older adults. Error bars represent standard deviation.

5.7.2.5 Table of linear models for neural activation and future time perspective for younger and older adult

Table A3

Linear models examining the effects of age group and future time perspective on brain activation for positive > negative contrast

	pgACC			**vmPFC**		
Predictors	*β*	*CI*	corrected *p*	*β*	*CI*	corrected *p*
(Intercept)	-21.25	-89.47 – 46.96	-	16.91	-55.11 – 88.93	-
Age Group	60.13	-15.83 – 136.08	0.16	11.02	-69.17 – 91.22	0.78
Future Time Perspective	9.15	-5.66 – 23.96	0.44	-2.07	-17.70 – 13.57	0.79
Interaction	-17.86	-34.90 – -0.82	0.06	-5.16	-23.15 – 12.83	0.57
Observations	49			49		
R^2 / R^2 adjusted	0.159 / 0.103			0.068 / 0.006		
	Right amygdala			**Left amygdala**		
Predictors	*β*	*CI*	corrected *p*	*β*	*CI*	corrected *p*
(Intercept)	-30.02	-64.54 – 4.50	-	-34.99	-60.49 – -9.49	-
Age Group	45.31	6.92 – 83.69	0.04	48.1	19.75 – 76.46	0.01
Future Time Perspective	2.92	-4.54 – 10.38	0.58	4.59	-0.92 – 10.11	0.4
Interaction	-8.71	-17.29 – -0.13	0.06	-9.66	-16.00 – -3.32	0.02
Observations	48			48		
R^2 / R^2 adjusted	0.238 / 0.187			0.313 / 0.266		

5.7.2.6 Figure of relationship between future time perspective and neural activation for younger and older adults

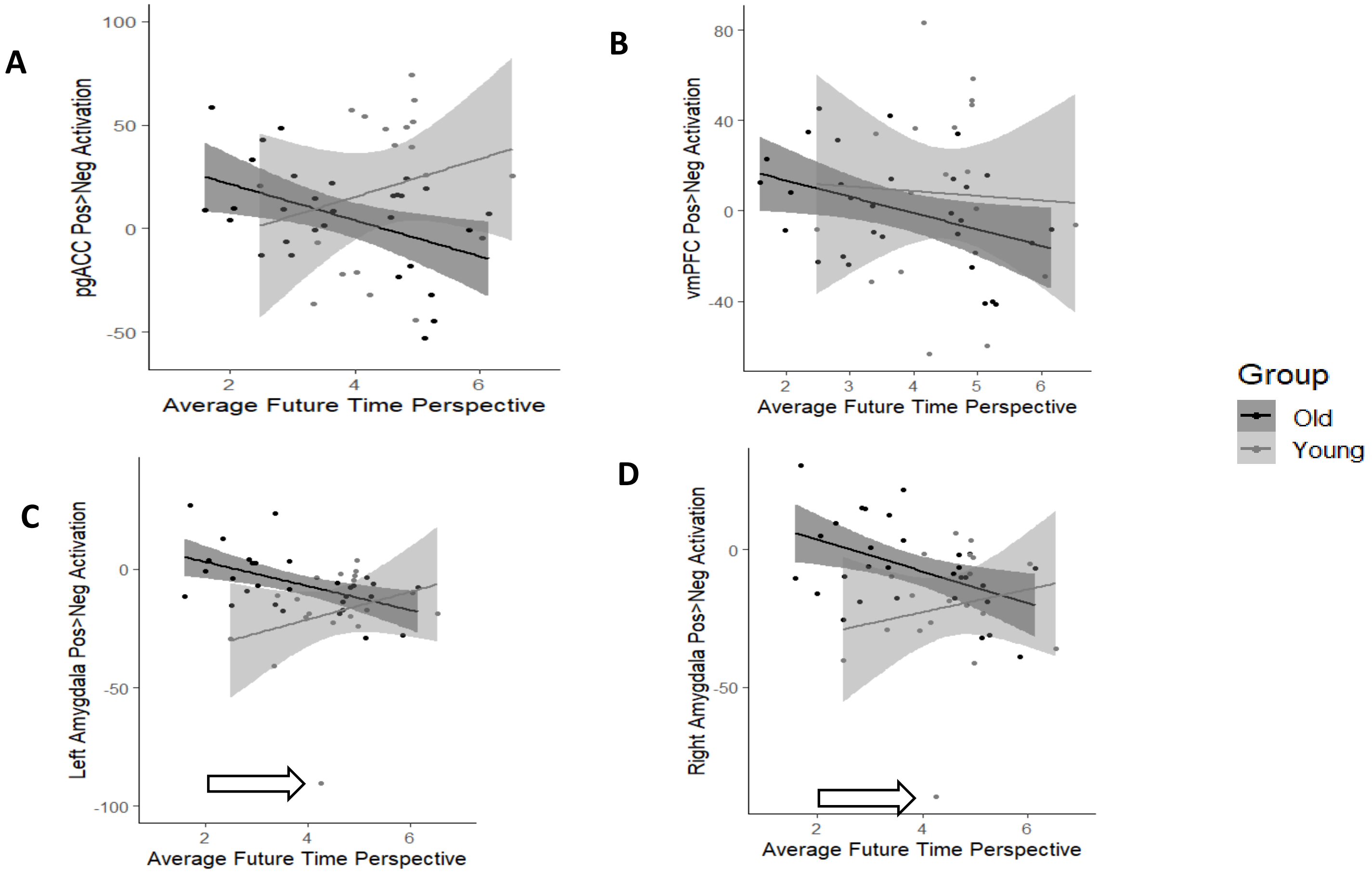

Figure A5. Relationship between future time perspective and positive > negative activity for A) pgACC, B) vmPFC, C) left amygdala and D) right amygdala for younger and older adults. Error bars represent standard errors. Arrows indicate outlier that was removed from analysis.

5.7.3 Appendix 3: Supplementary analysis – controlling for number of surveys

Since the number of surveys completed was significantly higher among older adults than younger adults, $t(50) = 4.11$, $p < .001$, follow-up analyses were conducted to include the number of surveys as a covariate in the linear mixed-effects models for the emotional well-being measures. The results show that there were no significant main effects of number of surveys for overall mood, β= .013, $t = .58$, $p = .57$, 95% CI [-0.03 – 0.06], frequency of negative emotion, β= -0.001, $t = -.06$, $p = .96$, 95% CI [-0.02 – 0.02], frequency of positive emotion, β= 0.01, $t = .75$, $p = .46$, 95% CI [-0.01 – 0.02] and intensity of negative emotion, β= -0.03, $t = -1.96$, $p = .05$, 95% CI [-0.06 – 0.00]. However, when number of surveys was added to the model for the intensity of positive emotion, the main effect of group is no longer significant, β= 0.39, $t = 1.59$, $p = .112$, 95% CI [-0.09 – 0.87]. Furthermore, when looking at the model for stress a greater number of surveys was significantly associated with lower levels of stress, $\beta = -.07$, $t = -2.31$, $p = .007$, 95% CI [-.12 - -.01].

5.7.4 Appendix 4: Supplementary analysis – follow-up amygdala contrast analysis

In order to examine whether the higher amygdala activation to positive > negative images was driven by increased amygdala responses to positive images or in fact reduced amygdala responses to negative images, follow-up analyses were conducted separately for both the positive > neutral contrast and the negative > neutral contrast.

Two separate multiple linear regressions were carried out to investigate whether average values of future time perspective and age group predicted average activation for the positive > neutral contrast and the negative > neutral contrast. In the negative > neutral model, an outlier was detected and was subsequently removed from the analysis.

For the positive > neutral contrast model, the results yielded no significant main effects or interactions, *p*s > .5. However, for the negative > neutral contrast, there was a main effect of group, β = -51.65, $t = -3.26$, $p = .004$ (corrected $p = .017$). Compared to younger adults, older adults had lower levels of left amygdala activation to negative > neutral images. There was also a significant group by future time perspective interaction, $\beta = 9.91$, $t = 2.80$, $p = .007$ (corrected $p = .03$). As such, these results suggest that future time perspective selectively affects amygdala activity to negative but not positive stimuli. In other words, our results suggests that a limited future time perspective is associated with maintained amygdala activity to positive stimuli and reduced amygdala activity to negative stimuli.

6. Chapter 6: General Discussion

The overall aim of this thesis was to investigate the effects of valence and age on long-term memories and to further our understanding of why older adults frequently demonstrate better memory for positive over negative stimuli compared to younger adults. As previously reviewed in Chapter 1, the importance of arousal in forming emotional memories, even for older adults, is well documented and has received a great deal of attention. However, understanding the separate effects of valence on memory is equally important, especially in terms of understanding the reasons for an age-related alternation in the effects valence has on memory. Therefore, in order to further our understanding in these areas, I firstly examined the effects of valence and aging on long-term autobiographical memory for a real-life event using an online longitudinal survey (Study 1; Chapter 3). By obtaining memory measures on four separate occasions, spanning between one and 64 weeks after the emotional event, we were able to assess how memories for a positive and negative event changed over time while considering the effects of chronological age. Next, we examined the interaction between valence and age on long-term episodic memory for emotional images presented in a controlled laboratory setting (Study 2; Chapter 4). Here, drawing on both behavioural and neural measures, we were able to distinguish the age-related neural differences during the processing of emotional information and considered how this may have affected long-term memory.

Finally, in order to understand how our previous findings compared to real-life experienced emotions, we explored the effects of valence and age on emotional well-being in younger and older adults (Study 3; Chapter 5). Here, we looked more closely at a theoretical framework (the Socioemotional Selectivity Theory) which provides an explanation for age-related differences in emotion, to determine whether this theory was sufficient to explain all of our neural, behavioural and subjective well-being measures. Overall, our results confirmed that there are indeed valence specific effects in memory (Study 1) that seem to change with age across both neural and behavioural measures (Study 2) which is further reflected in subjective well-being measures (Study 3) however, the current socioemotional selectivity theory does not fully account for all of our findings.

In this final chapter, I firstly summarize the findings of each empirical chapter separately, highlighting their individual strengths. I then consolidate the findings of the first two empirical chapters and discuss the consistencies and inconsistencies that were found between them. Subsequently, I critically analyse the weaknesses of these studies both individually and collectively but with broader limitations in mind. Finally, I then highlight their wider implications before making suggestions for future research.

6.1 Summary of Findings

6.1.1 Chapter 3. Memory of the U.K.'s 2016 EU Referendum: The effects of valence on the long-term measures of a public event.

In the first study (Chapter 3), we examined the effects of valence on people's memory for a real-life autobiographical event among individuals aged between 18 and 87. Though there is some research to suggest that there are valence specific effects for autobiographical memory, many are confounded by 1) the issue of using different events to represent positive and negative affect or by 2) using a limited number of follow-up assessments meaning that changes in memory measures cannot be longitudinally examined. In addition, to our knowledge, no previous studies have investigated the combined effects of valence and aging on the long-term maintenance of flashbulb memories. We therefore assessed people's memory for the U.K.'s 2016 EU Referendum, on four separate occasions spanning a total of 16 months in order to examine the effects of valence and age on memory consistency, vividness and confidence.

Since the previous literature provided mixed results for the effects of valence and aging on the formation of flashbulb memories, we did not have a specific directional hypothesis. Nevertheless, we expected that our U.K. participants would form stronger flashbulb memories in comparison to our U.S. participants since we expected them to consider the referendum results as more personally important and relevant.

Our results suggest that positive and negative public events are remembered differently, both initially and after a long-term delay. Notably, negative emotion was associated with more consistent memories whereas positive emotion was associated with increased memory confidence. From this, we concluded that the interpreted valence of the event led to differences in people's long-term autobiographical memory. However, we failed to find any significant age-related differences as a function of valence. The reasons for why this may be the case will be discussed later in this chapter. However there were significant age-related differences in our measures of positive and negative emotion obtained in Survey 1. Greater levels of positive emotion were all associated with increased age whereas the opposite was found for negative emotion; younger age was associated with higher levels of negative emotion. This pattern of initial levels of positive and negative emotion and aging fits with the wider literature which often finds that older adults are more likely to report greater levels of positive emotion but lower levels of negative emotion in comparison to younger adults (Carstensen et al., 2011); a topic which was explored further in our third empirical chapter.

6.1.2 Chapter 4. The Positivity Effect: Exploring age-related differences in the neural time course during emotional processing

Since there were several limitations to Study 1, such as being unable to randomly assign participants to a positive or negative emotion group while controlling for chronological age, we designed Study 2 with these limitations in mind. Firstly, we decided to conduct the study in a more controlled experimental setting where we could specifically recruit a group of younger and a group of older participants to explicitly test age-related differences in long-term episodic memory for positive, negative and neutral stimuli. In our previous experiment (Study 1), we had little control over the initial encoding of memory and could not completely rule out the possibility of differences in how the original memories were formed. Therefore, in Study 2 we designed an encoding task and explicitly measured behavioural and neural responses during the processing of emotional stimuli which allowed us to look more closely at the underlying mechanisms that support emotional memory formation which may contribute to the positivity effect often seen in memory. Another limitation associated with the previous study is that our findings may have been specific to the particular event we chose to assess peoples' memories for. Therefore, in Chapter 4, we used a standardized stimulus set, meaning we could 1) be more confident that any findings were not simply down to the stimulus we chose and 2) compare our findings to other studies that have used such images. In addition, since valence was as a within subjects factor in our previous experiment which prevented us from comparing an individual's memory for both a positive and negative event, valence was included as a within-subjects factor in Study 2. Finally, we were also unable to control for the effects of emotional arousal experienced in Study 1, meaning we cannot rule out the possibility that our results are the consequence of differences in levels of emotional arousal. As such, we controlled for the effects of arousal in Study 2 by creating stimulus lists that were matched on levels of arousal.

In this chapter, we continued our investigation into the effects of age and valence on long-term memory performance. A common finding within the emotional memory and aging literature is that older adults demonstrate a preference for positive over negative stimuli; a phenomena known as the positivity effect. According to the Socioemotional Selectivity Theory (SST), the reason for this change is due to a motivational shift that occurs with aging in which older adults concentrate more on emotional stability and positive affect. Consequently, they are considered to engage prefrontal brain regions that allow them to focus more on positive stimuli and selectively weaken amygdala activity to negative stimuli. However, whether this process is the consequence of older adults implementing cognitive control measures over time, is still uncertain. Therefore, in Study 2, we examined both the average activation and the temporal changes in the amygdala, vmPFC and pgACC to determine whether any age-related differences in brain activation were associated with behavioural measures of the positivity effect. We predicted that if the positivity effect arises due to older adults engaging in cognitive control over time, then they would show a selective reduction in amygdala activation to negative images and more sustained vmPFC and pgACC activation over time while processing the emotional stimuli.

Several of our findings from this chapter support the predictions made by the SST and cognitive control theory. For example, older adults, compared to younger adults, demonstrated a positivity effect in the behavioural memory measures and showed a reduction in general levels of amygdala activation specifically to negative stimuli. Furthermore, our time course analysis results of the pgACC also support the hypothesis that older adults increasingly engage prefrontal regions during emotional processing over time compared to younger adults. However, some of our findings were not entirely consistent with the SST and cognitive control theory. For example, we did not find any group differences in our general activation levels of the vmPFC or pgACC like we predicted. Likewise, when examining the temporal changes in the amygdala, older adults demonstrated similar behaviour to that of younger adults and showed similar levels of left and right amygdala activity to negative > neutral images and positive > neutral images over time.

Overall, however, our results offered more support for the SST and cognitive control theory than for the aging brain model and lend support to the idea that older adults may have implemented more controlled emotional processing over time that allowed them to reduce their negativity bias in memory and demonstrate the positivity effect.

6.1.3 Chapter 5. Examining the effects of future time perspective and age across measures of subjective well-being, memory and neural activation.

In the final chapter, we expanded on our results from the previous empirical chapter and sought to investigate daily experienced emotions among younger and older adults to understand whether there is any overlap between the positivity effect seen in behavioural and neural measures and better emotional well-being in daily life. The SST hypothesizes that as people get older, they become more aware that their time left in life is more limited and so prioritize short-term goals relating to maximizing emotional well-being over long-term goals of knowledge acquisition. However, many of the past experiments have examined emotional well-being in isolation from emotional memory yet the SST makes more general predictions about the age-related differences in emotional processing. In addition, there is evidence to suggest that a more limited future time perspective is in fact associated with poorer emotional well-being casting doubt over the theoretical predictions of the SST.

Therefore, in the final empirical chapter, we adopted a more naturalistic methodological approach by implementing an experienced sampling survey conducted outside of the laboratory. By studying participants' daily emotional experiences in real-life settings, we were able to achieve greater ecological validity than simply measuring mood during a laboratory visit. Using these measures to reflect subjective emotional well-being, we also utilized our behavioural memory measure from the previous empirical chapter as well as the neural activation data to positive > negative images and investigated the effects of future time perspective on these three independent measures. To our knowledge, no previous study has combined subjective well-being with behavioural and neural measures and examined the effects of future time perspective within the context of SST.

Overall, like our previous chapter, our results here provided mixed support for the SST. In line with recent research but contrary to the predictions made by the SST, we found that although older adults exhibited better emotional well-being (lower levels of negative affect and stress and higher levels of positive affect) than younger adults, a more limited future time perspective was indeed associated with poorer emotional well-being. Furthermore, a more limited future time perspective was not associated with greater positivity in memory. However, when examining the relationship between future time perspective and neural patterns of the positivity effect (which can manifest as increased activation to positive over negative images in the amygdala and/or the vmPFC and pgACC) we found that among older adults, those who considered their time left in their lives to be less expansive, exhibited increased left amygdala activation to positive > negative images.

6.1.4 Consolidating results between Chapters 3, 4 and 5.

As both Study 1 (Chapter 3) and Study 2 (Chapter 4) investigated the effects of valence and aging on episodic memory but used different methodological designs, they each provide useful information in how these factors affect the maintenance of long-term memory for emotional stimuli across both the laboratory and in the real-world. When considered separately, the two studies may seem too diverse for any meaningful comparisons to be made however, when taken together, we are able to understand how the effects of valence and age affect memory more widely. Likewise, although Study 3 (Chapter 5) focuses less on emotional memories and concentrates more heavily on the differences in experienced emotions in daily life between younger and older adults, one strength of evaluating the SST and testing the positivity effect within the same sample of participants across these chapters is that we can make direct comparisons between behavioural and neural responding during emotional processing and emotional well-being. Consequently, we are able to understand how emotional memories and emotional well-being may be linked and/or influenced by one another.

One overarching finding across the first two empirical chapters was that negative emotion enhanced memory to a greater degree than positive emotion did, even for older adults. From an evolutionary perspective, remembering negative stimuli that may be detrimental to our survival is beneficial. Though it is highly speculative to suggest that remembering the results of a political event would be relevant to our subsequent survival, it perhaps demonstrates that the basic mechanisms, designed to retain information that may jeopardize us in the future, can still be activated even when we simply interpret a non-life-threatening experience as negative. These main findings lend themselves to the idea that we typically demonstrate a negativity bias (Ito, Larsen, Smith, & Cacioppo, 1998) which can result in increased memory consistency and/or accuracy. Furthermore, according to our results, it is a bias that persists into later adulthood as has previously been documented (Murphy & Isaacowitz, 2008) despite the fact that older adults often demonstrate a positivity bias.

On the surface then, these findings may seem to contradict the idea of the positivity effect; that older adults should show a preference for positive versus negative information. While it is true that the most stringent definition of the positivity effect requires that older adults demonstrate a greater preference for positive versus negative information compared to younger adults (Mather, 2006) such as that seen in Charles et al. (2003) and Mather et al. (2004), Reed and Carstensen (2012) also maintain that the positivity effect can occur from the reduced processing of negative information among older adults relative to younger adults. In other words, it is also accepted that the positivity effect can manifest as a reduction in the negativity bias; a pattern that has frequently been found within the literature (Grühn, Scheibe, & Baltes, 2007; Mantantzis, Schlaghecken, & Maylor, 2020; Mather & Knight, 2005). As such, based on the findings of these two chapters, we would summarize that negative information has stronger facilitative effects on memory for both younger and older adults which fits with the wider literature in which negative memories are more vividly or accurately (Bowen, Kark, & Kensinger, 2018; Levine & Bluck, 2004) recalled whereas positive memories are associated with higher ratings of familiarity (Mickley & Kensinger, 2008) or increased confidence (Kensinger & Schacter, 2006).

However, that is not to say that emotional memory is entirely equal between younger and older adults. In fact, the results from our second study suggest that older adults did demonstrate age-related differences in emotional memory compared to younger adults. When examining our two final empirical chapters, we found combined support for the SST and more specifically the cognitive control extension of the SST. The SST is one of the main theories within the literature which helps to explain age-related differences in emotional processing including both memory performance and emotional well-being. Notably, we found behavioural evidence of the positivity effect in memory as well as several neural patterns of the positivity effect such as: 1) the selective reduction in amygdala activity to negative images among older adults when compared to younger adults (Study 2), 2) a significant increase in older adults' pgACC activity over time to emotional stimuli (Study 2) and 3) that among older adults, those who considered their time left in their lives to be less expansive, exhibited increased left amygdala activation to positive > negative images (Study 3).

Taken together, these results corroborate previous findings and suggest that there are age-related differences in emotional processing (see Kensinger, Allard, & Krendl, 2014; Mather, 2016 for reviews; St. Jacques, Winecoff, & Cabeza, 2013). While some may argue that our finding of a selective reduction in average levels of left and right amygdala activity among older adults to negative stimuli could offer support for the aging brain model

(Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011), our time course analysis of the pgACC would suggest otherwise. Instead, our findings align more with the idea that emotion regulation goals are more chronically activated compared to younger adults (Mather, 2012) due to their perception that time left in life is more limited. Therefore as a way of maintaining positive affect, older adults may have concentrated more on regulating their emotions while viewing the emotional images and could have implemented emotion regulation strategies to down-regulate negative affect. As such, the mnemonic advantage typically associated with negative images may have been reduced and resulted in a reduced negativity bias in memory performance. Our results therefore substantiate the cognitive control theory's extension of the SST and suggest that older adults gradually increase the engagement of prefrontal regions such as the pgACC during emotional processing to help regulate emotions. Although we are not able to prove whether this was due to older adults spontaneously engaging in emotion regulation efforts such as the down-regulation of negative affect, we can infer that the increasing activity of the pgACC reflects cognitive control efforts which may be important for the positivity effect.

Besides seeing age-related differences in neural patterns and behavioural data, we also found differences in the emotions experienced in daily life between younger and older adults. The results from our final empirical chapter suggest that there are also differences in the emotional profiles of younger and older adults. Here, despite their advanced aging and increased ill-health, the older adults in our study reported greater levels of positive affect as well as lower levels of negative affect and stress. Therefore the assumption that since older adults experience greater losses with age, they should experience increased negative affect or lower levels of well-being, seems to be misguided. In fact, this pattern of increased positive affect as well as reduced negative affect among older adults was also previously reflected in Study 1. Although we did not find any age-specific memory effects, we found a positive relationship between age and positive emotion but a negative relationship between age and negative emotion. Therefore, even in an entirely different sample of participants, chronological age was linearly associated with increased positive affect and decreased negative affect. In summary, the results from these final two empirical chapters indicate that while older adults may demonstrate a negativity bias in memory, albeit a significantly reduced one compared to that of younger adults, they are considerably distinguishable from younger adults in terms of their emotional well-being.

Across chapters 3 and 4, we did not explicitly assess the methods participants used to encode and consolidate their memories. Likewise, in our fifth chapter, we did not obtain a complete picture of younger and older adults' daily life to understand the reasons for their subjective emotional well-being ratings. Consequently, across all studies, certain assumptions had to be made that we could not directly assess. In Study 1 for example, we had to assume that, at least for the majority of our participants, that the EU referendum result elicited an emotional response that was sufficient enough to activate the biological and neural mechanisms that facilitate emotional memories. On the other hand, in Study 2, in order for us to interpret the results in a meaningful way, we had to assume that by asking participants to view static emotional images, we were in some way mimicking how humans would naturally respond to emotional stimuli in the real world. It is therefore reassuring that across all studies, there are consistent observations, despite their methodological differences and individual limitations.

6.2 Critical Evaluation: Strengths and Limitations

Across the three chapters, one notable strength is the variation in our methodological approaches. Though on the one hand, this may make it more difficult to make direct comparisons between studies, on the other, by drawing upon different experimental designs and approaches, we have been able to broaden the scope of our findings and identify areas for future scientific exploration. Generally speaking, laboratory-based research allows us to maintain more control of extraneous variables but it often does not necessarily reflect real-life experiences meaning that it is difficult to know how laboratory-based findings translate to the real-world. For example, as Kagan points out in his review on brain and emotion, the context in which we study emotion has important implications (Kagan, 2017). Often, through conducting experimental research, we place participants into unfamiliar contexts, such as in a laboratory or in an MRI scanner, and ask them to complete tasks that are far removed from real-life experiences which are unlikely to cause the same behavioural or neural responses that would occur in a more natural setting. Therefore, we would reason that our individual methodological designs complement one another and allow us to examine the effects of age on emotional memories more broadly and how it relates to emotional well-being in daily life.

Despite this particular advantage however, there are of course some limitations that should be considered. Therefore, in the next section specific strengths and limitations of each chapter are discussed in relation to one another and the reasons for inconsistent observations across experiments are considered. Following this, broader strengths and limitations across the thesis are discussed.

6.2.1 Critical discussion of Study 1 and 2

While we previously highlighted that there were some consistent findings across our first and second studies, there are some inconsistent findings that are important to discuss too. Importantly, in our first study, we did not obtain any evidence of the positivity effect in memory. It is possible that the reason for these inconsistencies is due to the methodological differences between the two studies, the most obvious being that the first study measured autobiographical memory while the second measured memory for stimuli learnt within the laboratory. However, according to the SST, the positivity effect *should* be evident in autobiographical memories too (Kennedy, Mather, & Carstensen, 2004; Schlagman, Schulz,

& Kvavilashvili, 2006; Tomaszczyk & Fernandes, 2012). That being said, when examining autobiographical memories, there appears to be a general tendency throughout adulthood to recall positive past experiences more frequently than negative ones (e.g. Schlagman et al., 2006; Walker, Skowronski, & Thompson, 2003). For example, Schlagman and colleagues (2006) found that although older adults recalled fewer negative memories such as accidents and stressful life events, both younger and older adults recalled a similar number of positive past events. These results suggest that while older adults demonstrated a reduced bias in recalling negative events which could be considered as evidence of the positivity effect, positive autobiographical memories are preferentially recalled across younger and older adults compared to negative ones. However, the SST does not make specific predictions about the effects of age on flashbulb memories. That being said, there is some evidence of age-related differences in flashbulb memories (see Kopp, Sockol, & Multhaup, 2020 for a review). However, since many flashbulb events are typically negative in nature, it is hard to know whether these age-related differences are the consequence of more general age-related memory declines or if they are in fact evidence of a reduced negativity bias among older adults. Therefore to explore this further, future research should consider examining age-related differences in flashbulb memory maintenance for both a positive and negative event.

Another reason for not finding age-related differences in Study 1 could be due to the personal relevance of the EU referendum results. Some studies have found that when information is considered to be personally highly relevant, the prevalence of the positivity effect is in fact reduced (Tomaszczyk, Fernandes, & MacLeod, 2008). Therefore, it could also be the case, that regardless of whether participants felt positive or negative about the event, those who decided to participate in our study found it more personally highly relevant than those who chose not to participate; hence why we did not detect age-related differences. Alternatively, since our sample of participants was an opportunistic one and since we used methods of recruitment that may have biased our sample in terms of demographics, it is possible that these could have masked any age-related effects. For example, our Leave participants were predominantly recruited via Prolific which has been shown to have a small sample of over 65s (Turner, Engelsma, Taylor, Sharma, & Demiris, 2021) yet we know that in the general population, Leave voters were typically older than Remain voters (Alabrese et al., 2019). Therefore, using the EU Referendum results as an event to investigate the effects of aging on flashbulb memory measures of consistency, confidence and vividness may have been susceptible to more general demographic biases beyond our control.

Another critical difference between the two studies concerns how and when the memories were assessed. One advantage of Study 2 is that we did not assess memory in isolation as we did in Study 1. Instead, we obtained neural data during the emotional processing of the emotional images which allowed us to examine age-related differences during this stage of memory formation more closely. Consequently, we could then use these measures to compare the findings with our subsequent memory performance data. In doing so, we gained a richer understanding of how emotional processing and emotional memories differ between younger and older adults. Our findings in Study 2 indicate that there may be important differences in the way in which younger and older adults initially encode emotional stimuli which is something we could not deduce from our previous study. For example, we found that older adults exhibited a selective reduction in amygdala activity to negative > neutral images compared to younger adults when viewing the emotional stimuli in the laboratory. Importantly, these findings dovetail nicely with our memory performance data in which we found evidence of the positivity effect in the form of a reduction in a negativity bias among older adults. Taken together, these results reflect the possibility that the way in which younger and older adults initially process emotional stimuli can lead to differences seen in memory.

Reflecting back on Study 1 then, one disadvantage of this experiment is that we measured memory one to two weeks after the referendum results with no assessment of how the groups may have differed in terms of processing or encoding the event in the first place. This retrospective approach could mean that there were already possible memory distortions or valence-related biases within the data. Another critical distinction between the two studies is that there may have been more frequent and explicit reminders of the EU referendum results over the course of the data collection period through news coverage on the TV and internet etc. whereas in Study 2, it seems unlikely that participants would have been exposed to the same or similar IAPS images in between experimental sessions and they viewed the images only once during the first experimental task. As such, it is likely the reminders in Study 1 affected initial and subsequent memories in some way which is less likely to be the case in Study 2. One measure we do have from Study 1 however is self-reported levels of rehearsal that could be used to infer differences in how the two groups encoded the event into memory. These particular findings highlighted that individuals who interpreted the event as negative (Remain voters) were more likely to engage in rehearsal, irrespective of age, which allowed them to form more consistent memories over time. Essentially then, it could be argued that negative memories were more strongly consolidated through means of rehearsal, regardless of a participant's age. Interestingly though, increased rehearsal has previously been shown to reduce the positivity effect among older adults. For example, when older adults were allowed to see emotional words more than once, positive and negative words were equally remembered (Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). Therefore, although one may predict, using the SST framework, that older adults would rehearse positive events more than negative ones (Breslin & Safer, 2013), it is possible that in this context, levels of rehearsal were influenced by external factors such as the media which may have ultimately masked any possible age-related differences.

6.2.2 Critical discussion of Study 2 and 3

Furthermore, it was also the case that the predictions of the SST were not uniformly supported across chapters 4 and 5 either. The underlying mechanism that is considered to explain both the positivity effect seen in attention and memory as well as positive emotional well-being in older adults is future time perspective. The idea is that with increasing age, older adults become more aware that their time is more limited which encourages them to concentrate on short-term goals that maximize positive affect. Although we found neural evidence to support this i.e. older adults who considered their time left in their lives to be less expansive, exhibited increased left amygdala activation to positive > negative images, a less expansive future time perspective was associated with poorer emotional well-being measures. In other words, chronological age and future time perspective had opposing effects on emotional well-being. As previous researchers have suggested, findings such as these do not necessarily completely refute the predictions of the SST (Grühn, Sharifian, & Chu, 2016). Instead, it may well be the case that older adults prioritize short-term goals that relate to emotional well-being because they are aware that their time left in life is limited but it does not necessarily guarantee that the change in motivations equates to changes in behaviour and/or mood (Grühn et al., 2016). Therefore, although emotion regulation goals may be chronically activated in older adults, the desired outcome still relies on the individuals' ability to successfully achieve the goal.

One might ask then *why do older adults experience increased emotional well-being despite still showing a negativity bias in memory (albeit a reduced one compared to younger adults)?* One possibility is that the difference in conditions between the laboratory setting and the real-life setting lent themselves to different resources being available to younger and older adults. According to the selection, optimization, and compensation with emotion regulation (SOC-ER) framework (Urry & Gross, 2010), the types and amount of resources available to younger and older adults changes with age. For example, older adults may have lower levels of cognitive control compared to their younger counterparts (Opitz, Rauch, Terry, & Urry, 2012) but they are also known to have smaller yet closer social networks (Carstensen, Fung, & Charles, 2003) which is known to influence well-being (Charles & Carstensen, 2010). Therefore, while younger adults may rely more heavily on their resource of cognitive control in emotional situations, older adults may utilize other resources, like social relationships, to compensate for the resources they have less of. The SOC-ER expands on the process model of emotion regulation (Gross, 1998) and suggests that the resources that are available to younger and older adults may influence their choice of emotion regulation strategies (Urry & Gross, 2010). Therefore, in daily life, older adults may have had access to more resources compared to those that were available to them in the laboratory and these resources may have helped them to regulate their emotions more effectively in daily life. On the other hand, in the laboratory, participants were faced with emotional stimuli and could not therefore choose for example, the emotion regulation process of situation selection whereby they could have avoided the situation altogether like they may do in real-life. Instead, it is likely that older adults had to rely on cognitive control given that their access to other resources was limited. Fundamentally, the types of emotion regulation strategies that are implemented by older adults in daily life are unlikely to be the same strategies they were required to use within the laboratory which is why it may be difficult to make direct comparisons between the two. Taking the results from all chapters, the findings collectively suggest that while it may be true that older adults experience better emotional well-being with age, it does not prevent them from demonstrating similar patterns of emotional memory to younger adults i.e. a negativity bias, albeit a reduced one.

Finally, it is also worth highlighting that across Chapters 4 and 5, we did not find any significant effects of the vmPFC. This may seem surprising given that the vmPFC is widely considered to be important in both cognitive and emotional processing and is considered to be particularly important for the regulation of negative emotions (Hiser and Koenigs, 2018). Importantly, many functional neuroimaging studies investigating the effects of aging on emotional processing have found an age-related increase in PFC activation (Leclerc & Kensinger, 2008, 2011; Urry et al., 2006; van Reekum et al., 2018). Therefore, if the positivity effect arises due to older adults implementing goal-directed behaviour that allows them to ignore negative and concentrate more on positive information, one would expect to see increased activity within the vmPFC which could reflect cognitive control and emotion regulation efforts.

That being said, other studies, like ours, have also failed to find age-related increases in PFC activation when participants are presented with emotional films (Schweizer et al., 2019) or when they are asked to regulate their emotions through reappraisal techniques (Opitz et al., 2012; Winecoff, LaBar, Madden, Cabeza, & Huettel, 2010). Likewise, other studies have found similar patterns of vmPFC activity between younger and older adults when participants are presented with happy faces (Keightley, Chiew, Winocur, & Grady, 2007) suggesting that younger and older adults may rely on similar neural regions when processing positive stimuli. Nevertheless, we did expect to find age-related differences in the vmPFC but instead, only found a significant age-related difference in the pgACC.

One possibility for this is that the vmPFC is situated ventrally and so may have been more susceptible to signal loss (Ojemann et al., 1997; Urry et al., 2006) which may have prevented us from obtaining maximum statistical power to detect any age-related differences. That being said however, given the proximity of our two frontal ROIs (the vmPFC and pgACC), signal dropout will likely have affected both regions and therefore does not account for our significant findings in the pgACC. Another possibility is that since the vmPFC does not represent an anatomically defined area and is in fact comprised of several sub-regions within the prefrontal cortex (Lopez-Persem, Verhagen, Amiez, Petrides, & Sallet, 2019), it makes it more difficult to directly compare findings in the previous literature, especially as sometimes the vmPFC comprises of areas of the ACC (e.g. Addis, Leclerc, Muscatell, & Kensinger, 2010; Leclerc & Kensinger, 2008, 2011). As such, future MRI studies investigating age-related differences in emotional processing could benefit from using ROI masks from meta-analyses such as the one we used in this thesis.

A third possibility is that the pgACC and the vmPFC may be associated with different processes. As mentioned in the Introduction, the vmPFC is thought to be a key region during emotion regulation since several studies have found an inverse coupling between vmPFC and amygdala activity in response to negative stimuli (Ochsner, Bunge, Gross, & Gabrieli, 2002; Urry et al., 2006). As such, the vmPFC is thought to play a critical role in the down-regulation of negative affect (Phelps, Delgado, Nearing, & LeDoux, 2004; Yang, Tsai, & Li, 2020). For older adults, the vmPFC is also thought to be differentially activated for positive versus negative stimuli with some studies finding greater vmPFC activity to positive over negative stimuli which is in stark contrast to the pattern seen among younger adults (Leclerc & Kensinger, 2008) and is therefore thought to reflect the "positivity effect". Besides these findings, the vmPFC has also been implicated as an important area for maintaining older adults' emotional well-being (Williams et al., 2006). Therefore, overall, there is a great deal of evidence to suggest that the vmPFC is inherently linked to affective processes which was further substantiated in a more recent meta-analysis from which we obtained the vmPFC ROI mask (de la Vega, Chang, Banich, Wager, & Yarkoni, 2016).

However, it is also the case that the vmPFC has been identified as a key region in a number of different functions that extend beyond emotion and emotion regulation (for reviews see Hebscher & Gilboa, 2016; Hiser & Koenigs, 2018; Roy, Shohamy, & Wager, 2012). For example, the vmPFC has been implicated in goal-directed behaviour (Hare, Camerer, & Rangel, 2009), decision-making (Bechara, Tranel, & Damasio, 2000), and self-relevant processing (D'Argembeau et al., 2005; Johnson et al., 2002) to name a few. Therefore, rather than the vmPFC being uniquely involved in affective processing, some researchers have suggested that the vmPFC is more broadly involved in meaning-related processes and consider it to be more like a hub that connects other brain regions to undertake more specific functions (Roy et al., 2012). Therefore, the vmPFC's role may not be specific to emotion regulation per se but it may play a facilitative role along with other brain regions.

On the other hand, the pgACC has been implicated as a key structure in mediating cognitive control (Ochsner & Gross, 2005; Pessoa, 2009) especially in the presence of emotional stimuli. As such, the area has been shown to respond during occasions where an emotional stimulus may interfere with task-relevant processing (Bishop, Duncan, Brett, & Lawrence, 2004; Mohanty et al., 2007). Since we required our participants to participate in a task in which they had to indicate whether each image was 'indoor' or 'outdoor', the emotional aspect of the stimuli may have interfered with this task-relevant processing. Therefore, the increase in pgACC activity over time may reflect older adult's greater reliance on this area when task-irrelevant information is distracting due to its emotional content. Taken together, it may be the case that the vmPFC plays a broader role in affective processing that is not always affected by age and that the pgACC has a more specific role in cognitive control that is particularly prevalent among aged individuals who may rely on this area more when task demands are greater.

6.2.3 Potential effects of mood in Study 2

When examining Study 2 in isolation, it is worth highlighting that some of our age-related differences could also be a consequence of differences seen in younger and older adults’ mood at the start of the experimental session (previously discussed in Chapter 4). Generally speaking, our mood is known to influence our cognition and our memory is no exception (Forgas & Eich, 2013). Therefore, if an individual is in a positive mood, they are predicted to demonstrate mood-congruent memory, i.e. they are more likely to recall positive information that is congruent with how they feel (Bower, 1981). Since the older participants in Study 2 and 3 reported greater levels of positive affect but lower levels of depressive symptoms compared to younger adults at the start of both experimental sessions, it could be that their mood not only influenced memory encoding processes but also retrieval. Indeed, previous research has found that older adults are able to maintain their positive mood by concentrating more on positive than negative information (Isaacowitz, Toner, & Neupert, 2009) meaning that it is more likely that they will successfully encode the positive information. It is also the case that, compared to younger adults, older adults are more likely to engage in mood-incongruent processing when they are in a negative mood. On these occasions, they concentrate more on positive information which is considered to reflect their attempts at regulating their current mood (Isaacowitz, Toner, Goren, & Wilson, 2008).

6.2.4 Considering the effects of arousal

According to some researchers, arousal and not valence is what facilitates emotional memory (e.g. M. M. Bradley, Greenwald, Petry, & Lang, 1992; Mather, 2007) however others highlight the importance of understanding how valence affects encoding processes (for a review see Kensinger, 2009) which has important implications for emotional memory. Importantly, some of our results within this thesis support the latter argument; that valence can in fact lead to differences in certain memory measures such as consistency and confidence. Nevertheless, by concentrating more specifically on valence rather than arousal in this thesis, an important limitation in both Study 1 and Study 2 to consider is that we did not obtain explicit measures of arousal which could have equally contributed to the group-related differences we found.

While we were able to control for the effects of arousal in Study 2 by ensuring that our positive and negative image lists were matched on arousal ratings, we did not obtain subjective arousal ratings from the participants in any of our studies like we did for valence. Ultimately, this means that we cannot be certain about the effects arousal may have had in either study nor do we know whether there were group-level differences in how arousing they found 1) the EU Referendum event or 2) the emotional images used in Study 2. This is problematic for several reasons. Firstly, Keil and Freund (2009) previously found a linear relationship between arousal ratings and emotional valence among older adults. In their study, older adults rated less arousing images as most pleasant and highly arousing images as most unpleasant suggesting that levels of arousal may have contributed to their evaluation of a picture's valence. Further evidence of this arousal-valence relationship comes from another study in which older adults were more likely to provide lower arousal ratings after watching a positive film clip but higher ratings of arousal after watching a negative film clip (Fernández-Aguilar, Ricarte, Ros, & Latorre, 2018). Likewise, Grühn and Schiebe (2008) found that older adults provided more extreme ratings than younger adults for valence but lower levels of arousal levels for positive images and higher levels of arousal for negative images. Interestingly, the positivity effect has sometimes been found to be strongest when the stimuli are low in arousal (Kappes, Streubel, Droste, & Folta-Schoofs, 2017) or to be weaker under high arousal conditions (Streubel & Kunzmann, 2011) meaning that younger and older adults sometimes remember high arousal stimuli equally, regardless of positive or negative valence (Kensinger, 2009). Therefore, the relationship between valence and arousal remains a complicated one that is difficult to completely tease apart and is one that may equally change with age.

As such, future research should consider experimental designs that allow for levels of arousal to be controlled for. For example, obtaining explicit ratings of arousal from younger and older adults is a viable option but researchers should consider how an explicit rating task like this may affect subsequent task performance. An alternative method would be to utilize psychophysiological methods such as skin conductance or pupil dilation which are considered to indirectly measure arousal responses. However, it is worth highlighting that it is also the case that there are often age-related differences in physiological responses to arousing material too (Burriss, Powell, & White, 2007; Smith, Hillman, & Duley, 2005; Tsai, Levenson, & Carstensen, 2000) and they do not always correspond with subjective measures of arousal either. For example, when examining such as skin conductance and heart rate responses to IAPS pictures, older adults exhibited weaker responses compared to younger adults despite providing more extreme arousal ratings (Burriss et al., 2007). As such, in order to to fully understand the age-related reversal in the effects valence has on emotional memory, arousal should also be considered and/or measured through subjective and physiological methods.

6.2.5 Evaluating the use of stimuli

Perhaps one limitation associated with our initial study is that the ‘stimuli’ we used to test memory was an incredibly unique political event. While there are other flashbulb memory studies that have examined an event that has yielded a positive outcome for some and a negative outcome for others (e.g. Breslin & Safer, 2011; Kensinger & Schacter, 2006), only a few have looked more specifically at a political event (e.g. Chiew, Harris, & Adcock, 2021; Conway et al., 1994; Holland & Kensinger, 2012) and among these, the evidence for specific effects of valence on memory is mixed. Consequently, it means that our results could be dependent upon the particular characteristics of the chosen event. Therefore, although our methodological design allowed us to compare a single event that yielded both a positive and negative outcome for which we could control event-related properties, it cannot be compared to other studies as easily as those that include standardized stimulus sets can.

Adding to this, we also found evidence of age-related differences in the ways in which younger and older adults rated the event in terms of personal importance and surprise. More specifically, we found that increasing chronological age, regardless of voting group, was associated with higher levels of importance and surprise suggesting that there may have been fundamental differences in the ways in which younger and older adults initially appraised the event. Although these age-related differences did not contribute to our main memory measure findings, it highlights the possibility that such differences could have influenced early emotional processing including encoding between younger and older adults.

In Study 2 therefore, a standardized stimulus (IAPS images) was used so that we could be more confident that our results were not specific to our chosen stimuli. However, it is important to note that the normative ratings for IAPS images are based on younger adults' responses and there is evidence to suggest that there are age-related differences in the ratings of the International Affective Picture System (IAPS: Lang, Bradley, & Cuthbert, 1997). For example, when younger and older adults were asked to provide self-assessment manikin ratings of valence and arousal, Backs and colleagues found significant differences in the ratings of positive images (Backs, da Silva, & Han, 2005). Interestingly, younger adults rated pleasant-arousing pictures as more arousing than older adults did. While the authors suggest that these group differences could be explained in terms of younger adults experiencing greater affect intensity in combination with greater levels of emotional control, the authors equally speculate that younger and older adults may have appraised the images differently.

Therefore, before conducting the main experiment, we ran an online study in order to select the images that younger and older adults similarly rated in terms of valence and arousal. While we recruited 29 older adults (*M*age = 63.62 years, SD=2.59) and 33 younger adults (*M*age = 27.19 years, SD = 4.39), we had to exclude responses from 41% of older adults (*n* = 12) and 55% of younger adults (*n* = 18) as they provided data (i.e. gave the same arousal ratings on consecutive trials for more than 33% of the trials) to suggest that either they did not understand the arousal rating question or that they were simply partaking in the experiment for the monetary reward. Consequently, due to our small sample size, we cannot be confident that our results would be replicable using a different sample of participants. As such, a higher powered study would be required in order to be more confident in our findings.

6.2.6 Considering the reliance on specific participant samples

Over the years, online research has become a popular avenue for scientific researchers to conduct research since data can be collected from a large number of participants at a relatively low-cost and over a short space of time that would otherwise take several months using more traditional methods (Weinberg, Freese, & McElhattan, 2014). Though the shift towards using online methods was initially met with some scepticism surrounding the quality and validity of the data recorded, more recent studies have found that online research using participant samples from platforms such as MTurk are not compromised in terms of data quality that one associates with more traditional experimental methods (Buhrmester, Kwang, & Gosling, 2016; Peer, Vosgerau, & Acquisti, 2014) and can even sometimes be superior to laboratory-based data collection (Casler, Bickel, & Hackett, 2013). Therefore, one notable strength of our first study was that it was done online and allowed us to access a larger and arguably more diverse sample of participants beyond the University student community. Consequently, it is likely that our sample more closely reflects that of the U.K. and U.S. populations than it would have if we had simply recruited undergraduate students. For this study in particular, recruiting participants beyond our undergraduate sample was particularly important since previous research has implied that there are significant political differences between adults who have completed higher education compared to those who have not (Pew Research Center, 2016). Therefore, since our study concerned a political event, it was important to diversify our sample as much as possible.

For our second and third studies however, we relied upon a participant pool comprised of students who participated for course credit and a University research database listing local older adults. By relying on such samples, it is likely that our samples do not necessarily reflect the wider population. For example, young adults in higher education are susceptible to experiencing high levels of stress due to examinations and coursework, money problems, loneliness and relationships and have been found to exhibit higher levels of elevated stress (measured using blood pressure) around the times of examinations (Hughes, 2005). As a consequence, this means that compared to the general population, students in higher education are often more likely to experience higher levels of mental health problems (Stallman, 2010) including depression (Ibrahim, Kelly, Adams, & Glazebrook, 2013). This has important implications in terms of our results since we explicitly measure positive and negative affect in Study 3. Therefore, our age-related differences could be stemming from our younger adults, who were mostly students, reporting general levels of low-mood. In addition, according to the scores on the CES-D in Study 2, many of our student population would be classified as being ‘at risk’ for clinical levels of depression since they score above the cut-off score of 16/60. Moreover, when converting our CES-D data to percentile ranks using software developed by Crawford, Cayley, Lovibond, Wilson, and Hartley (2011), the average score among younger adults (M = 15.6) equates to a percentile rank of 61 suggesting that 61% of the general population aged between 18 and 24 would be expected to score lower than the average obtained by our younger adults. In other words, our younger adults are possibly scoring above average on the CES-D. Nevertheless, it is important to remember that the

CES-D is not a clinical tool to diagnose depression but rather is a tool that aids in identifying those at risk of clinical depression.

It is also well known that depression is associated with cognitive deficits in memory (for a review see Rock, Roiser, Riedel, & Blackwell, 2014) and that memory can be influenced by an individual's current mood (e.g. mood-congruent theory; Mayer, McCormick, & Strong, 1995). Therefore, it is possible that some of our findings may have been skewed by these participants. Future research would therefore benefit from recruiting participants beyond student samples and could use questionnaires such as the CES-D as a screening tool in order to exclude any participants who may be showing sub-clinical levels of depression or anxiety.

Comparatively, our reliance on a university database that contained local older adults could mean there are differences in the motivations for taking part in research compared to students. Older adults may be more enthusiastic and curious about taking part compared to students who are often required to participate for course credits. Likewise, many of the older adults included in our experiments had previously been invited to similar studies meaning that they could have predicted that their memory for example would be later tested. It is also the case that we were required to exclude many older adults based on medical conditions which prevented them from being able to undergo an MRI scan as well as excluding participants who showed signs of memory impairments. As such, our sample of older participants may be biased towards those that are physically healthier, who are higher functioning than other community-dwelling older adults of a similar age and are more motivated to take part in experimental research. Therefore, older individuals who are in a better state of physical health, who are still able to undertake social activities and maintain high levels of independence may naturally show elevated levels of positive affect compared to older adults with health problems who are consequently limited in what activities they can do.

6.2.7 Exploring the possible effects of gender/sex

In our initial study, while we did find that our groups differed in terms of sex, our results remained the same even after controlling for these demographic differences. However, one shared limitation of Study 2 and 3 is that our age groups were not equally matched in terms of gender. While the gender balance among our older participants was more or less equal, our younger group comprised more heavily of female participants (females: 18; males: 7) most likely due to the fact that they were predominantly undergraduate psychology students. Although the aim of this thesis did not intend to consider the effects of gender on emotional memories, there is evidence to suggest that men and women react differently to emotional material (M. M. Bradley, Codispoti, Sabatinelli, & Lang, 2001; Gard & Kring, 2007). As such, it is an important limitation to consider.

Generally speaking, females are considered to be the more “emotional sex” (Nolen-Hoeksema, 2012) and are deemed to be more sensitive to emotional stimuli, often reporting higher levels of emotional intensity compared to males (Grossman & Wood, 1993; Poláčková Šolcová & Lačev, 2017). When looking more specifically at emotional memory, females often exhibit superior memory (Bloise & Johnson, 2007; Canli, Desmond, Zhao, & Gabrieli, 2002) and report higher levels of memory vividness (Seidlitz & Diener, 1998) compared to males. There is also evidence to suggest that males and females differ in emotional well-being with men reporting positive emotions more frequently and women reporting negative emotions more frequently (for a review see Simon, 2014). Therefore, it may be the case that the age-related differences seen in our diary data are being driven by the higher proportion of younger female participants who may have been more likely to report negative affect.

Importantly, these sex differences are also thought to extend to the brain (for a review see Cahill, 2006) with some evidence of sex-related hemispheric lateralization of amygdala function in emotional memory (Cahill, Uncapher, Kilpatrick, Alkire, & Turner, 2004 however, see; Wager, Phan, Liberzon, & Taylor, 2003 for an alternative view) with women showing enhanced right amygdala activity to negative over neutral images compared to males (Domes et al., 2010). Interestingly, there is also evidence to suggest that the time course of emotional processing is different between that of males and females (Gard & Kring, 2007) possibly reflecting differences in the regulation of their emotional response.

6.3 Wider considerations and recommendations for future research

Overall our findings highlight the importance of understanding the separate and combined effects of valence and aging on emotional memory and emotional well-being and confirm that there are age-related differences in emotional processing. Although there is extensive research across all of these areas, this thesis aimed to synthesize findings across different domains, including autobiographical memory, episodic memory and subjective well-being in order to gain a wider understanding of how and why these age-related changes occur. We particularly concentrated on the effects of valence rather than arousal with the specific aim to understand the reasons for the age-related reversal in the effects valence has on memory.

6.3.1 Reflecting on the definition of emotion

In this thesis, I defined emotion using Russel's Circumplex Model of Affect (1980) whereby emotion is comprised of two dimensions: valence and arousal. Within this framework, different emotional states are characterized by both valence and arousal. For example, an individual who experiences high levels of negative arousal may be feeling angry or upset whereas an individual who experiences low levels of positive emotion may feel calm or relaxed. However, as previously mentioned in the Introduction, there is no single agreed-upon definition of what constitutes emotion. Instead, some researchers define emotion in terms of separable motivational systems such as appetitive-defensive (Lang, Bradley, & Cuthbert, 1990) and approach-withdrawal, while others define emotion in terms of discrete states such as fear and happiness which are further evidenced in psychophysiological measures such as facial expressions (Ekman & Friesen, 1971). As such, the interpretability of the results generated in this thesis should be considered more specifically within the context of how we initially defined 'emotion' i.e. in terms of valence and arousal. Therefore, although our results offer important contributions to the literature on the effects of valence on memory, it is equally important to consider the limitations associated with how we measured and conceptualized emotion throughout this thesis.

According to some researchers, defining emotion using levels of valence and arousal masks the important qualitative differences in discrete emotions such as anger versus fear or happiness versus pride. In fact, many studies have found that discrete emotions can differentially impact peoples' behaviour including the judgements and decisions they make (for a review see Angie, Connelly, Waples, & Kligyte, 2011). Likewise, a locationist view of emotion assumes that certain emotions such as anger, fear and happiness produce a distinctive pattern of outputs that are represented by the body and the brain. For example, people can detect fear in others by the facial expressions they display just as they can for happiness. When looking more specifically at memory, discrete emotions such as disgust for example, have been shown to result in higher levels of memory recognition compared to fear and sadness (Chapman, Johannes, Poppenk, Moscovitch, & Anderson, 2013; Croucher, Calder, Ramponi, Barnard, & Murphy, 2011; Marchewka et al., 2016).

Understanding emotion in this way derives from appraisal theories of emotion which help to explain the differentiation of emotional experiences. Appraisal theorists argue that emotions are the result of an individual's unconscious evaluation of an event depending on their current goals which then give rise to the person subsequently experiencing a particular emotion like happiness (Arnold, 1960; Sander, Grandjean, & Scherer, 2005; Scherer, 2001). To put it more simply, emotions are the consequence of an individual's appraisal of a certain situation (Roseman & Smith, 2001). Importantly, it means that there can be high levels of variability both across and within individuals in terms of an emotional response. Applying this logic to the current thesis, it means that an emotional event, such as the EU Referendum results that we assessed in Study 1, may not necessarily evoke the same emotional response in every person since there could be differences in the way in which the event was initially appraised. While we considered that there would be group-level differences in terms of valence, i.e. we predicted that Remain voters would experience more negative emotions compared to those who voted to Leave, we did not necessarily consider the differences in the initial appraisal of the event. As such, a Remain voter who dedicated many hours to campaigning with the aim of winning the election may have, after having learned the results, considered that their efforts were not sufficient to obtain their goal and subsequently may have felt disappointed. Meanwhile another Remain voter, may have strongly disapproved of some of the opposition's campaign messages meaning that they subsequently experienced anger when they learnt that Leave voters won. While both emotions are deemed to be negative, the individual variability in the initial appraisal and the subsequent discrete emotions that they experienced may have influenced memory encoding differently. Although we did obtain measures of discrete positive and negative emotions, we averaged them together to create a single positive emotion and negative emotion score rather than examining the individual effects of each separate emotion on memory. Consequently, by measuring emotion in this way, we may be masking individual effects of the discrete emotions.

We undertook a similar approach of averaging positive and negative emotions in our final empirical chapter too since aging is frequently characterized by increases in positive affect and decreases in negative affect (Carstensen et al., 2011; Charles, Mogle, Urban, & Almeida, 2016). However, there is in fact research to suggest that the experience of discrete negative emotions such as anger and sadness show different developmental trajectories (Kunzmann, Kappes, & Wrosch, 2014). For example, older adults frequently report less anger (Blanchard-Fields & Coats, 2008) and sometimes report greater levels of sadness (Seider, Shiota, Whalen, & Levenson, 2010). Likewise, older adults have been found to experience higher levels of calmness but lower levels of excitement compared to younger adults (Hamm, Wrosch, Barlow, & Kunzmann, 2020). Therefore, while the results from our diary study investigating emotional well-being between younger and older adults are consistent with previous literature, by averaging together positive and negative emotions as opposed to looking at them independently, we may be masking nuanced differences in discrete emotions that could contribute differently to emotional well-being.

Returning back to our first empirical chapter, within the flashbulb memory literature, researchers often consider the appraisal of an event, like the EU Referendum results, in terms of importance, consequentiality and surprise (Er, 2003; Finkenauer et al., 1998; Tinti, Schmidt, Sotgiu, Testa, & Curci, 2009) but to the best of our knowledge, none have necessarily considered the effects of discrete emotions such as fear or sadness or conversely happiness or excitement on flashbulb memory formation and maintenance. This may explain why there are many inconsistencies within the literature. Therefore, understanding the variability in peoples' appraisal of an emotional event is important, especially when different emotions of the same valence can lead to different outcomes in memory. Levine and Burgess (1997) for example, examined the effects of discrete emotions on subsequent memory performance for a narrative. In the study, undergraduate students were firstly given a surprise quiz in which they received either a high grade, 'A' or a lower grade, 'D'. Participants were then randomly assigned to either the positive condition (grade A) or negative condition (grade D) before taking part in a secondary task during which they heard and recalled a narrative. They also provided their primary emotional reaction (e.g. happiness, anger, sadness, fearful and *other*) in response to receiving their grade. Based on these self-reported emotions, feelings of happiness led to better overall memory performance whereas feelings of sadness led to better memory performance for the outcome of the narrative and anger led to better memory performance for the consequences. Taken together, these results highlight the possibility that discrete emotions can influence the way in which events are remembered and further suggest that a persons' initial emotional state may influence what becomes central in memory. With this in mind, it may be the case that the central information for Leave voters differed to that of our Remain voters. Perhaps the central information for them concerned the factual evidence of the EU referendum results as opposed to the context in which they learnt them. Therefore, one possible direction for future research would be to explore the effects of discrete emotions on the subjective and objective measures of flashbulb memory formation.

This consideration of the appraisal theory of emotion and the effects of discrete emotions on subsequent memory also applies to Study 2. Some of the images that are included in the IAPS data set, though categorized as negative and highly arousing, could evoke different emotions such as fear versus anger. From an appraisal perspective, it is important to distinguish emotions in this way since they are thought to influence attention and memory in different ways. For example, feelings of fear and feelings of disgust are both considered to be arousing negative emotions yet studies have shown that stimuli eliciting feelings of disgust are recalled better than stimuli eliciting feelings of fear (Chapman et al., 2013; Croucher et al., 2011). Findings such as these therefore, cast doubt upon whether a two-dimensional view of emotion (i.e. using valence and arousal) is sufficient in determining the effects of emotion on cognition. Since we did not consider the single effects of discrete emotions on memory across any of our chapters, it is an important limitation to consider.

In relation to this, although we obtained valence ratings for each image, we do not know how each individual, irrespective of age-group, initially appraised or interpreted each separate image when viewing them for the first time in the MRI scanner. Since there is great variability in the types of emotional scenes included in the IAPS data set, it is possible that a scene may evoke anger for one person but sadness for another. Such differences in emotional responses could also have been amplified by differences in age. When comparing younger and older adults, research has shown that despite experiencing the same or a similar event or situation, older adults, compared to younger adults, sometimes report differences in the subsequent emotions they experience or in the intensity in which they feel them (Kunzmann, Rohr, Wieck, Kappes, & Wrosch, 2017; Kunzmann & Thomas, 2014; Löckenhoff, Cook, Anderson, & Zayas, 2013). As such, it could be that there are age-related differences in how younger and older adults initially appraise an event or stimulus which then leads to differences in the types of emotions they experience. One example of this comes from a study that found that when younger and older adults were exposed to mild levels of social exclusion, older adults reported feeling less negative than younger adults did (Löckenhoff et al., 2013) suggesting that there may have been differences in the way in which younger and older adults appraised being socially excluded. Likewise, when younger and older adults were asked to recall a single autobiographical event that they associated with sadness or anger, older adults reported less intensity for feelings of anger than younger adults did (Kunzmann et al., 2017). With this in mind, it is important to acknowledge that there may have been significant individual differences in peoples' emotional response to the same stimuli (Kuppens & Tong, 2010) that may have influenced memory encoding processes differently and that age differences could equally have affected this too. As such, future studies examining age-related differences in emotional memory could benefit from understanding whether the positivity effect is the consequence of differences in initial appraisal or if it is due to other factors such as differences in memory consolidation processes, for example. Indeed, a very recent theory, coined the Appraisal Approach to Aging and Emotion (AAAE: Young, Minton, & Mikels, 2021) considers how age-related changes in cognitive and physical abilities as well as shifts in motivations may contribute to differences in appraisal between younger and older adults which may ultimately lead to differences in emotional experiences.

In relation to the argument presented above, another recommendation for future research investigating age-related differences in emotion would be to consider whether the interpretation and experience of emotion is the same across younger and older adults. An assumption we made across Study 1 (Chapter 3) and Study 3 (Chapter 5) in this thesis, is that the meaning of each emotion was similar between younger and older adults. However, emotions such as happiness and sadness are sometimes thought to be interpreted differently by younger and older adults (Mogilner, Kamvar, & Aaker, 2010; Ready, Santorelli, & Mather, 2017). Rather than having a 'fixed' meaning, research has indicated that the meaning of emotions like happiness are thought to shift with age. For example, in one study, researchers investigated what younger and older adults associated with feelings of happiness and found that younger people associated happiness with excitement whereas older adults associated happiness with peacefulness (Mogilner et al., 2010). Therefore, better emotional well-being measured as increased happiness among older adults could in fact be driven by feelings of calmness and contentment over excitement or interest. This age-related shift in meaning dovetails nicely with the SST's age-related shift in goals. Since older adults are thought to concentrate more on present-focused goals, it makes sense that they may report more present-focused emotions such as 'calmness' over future-focused emotions such as 'excitement'. Future research investigating age-related differences in emotional well-being could benefit from investigating this concept further.

6.3.2 Considering the role of self-referential processing

Another element that is central to many appraisal theories is the idea of self-relevance (Scherer, Schorr, & Johnstone, 2001) which has been considered as one possible explanation for the positivity effect (Leclerc & Kensinger, 2008). Moreover, it is also an important concept for autobiographical memories since they are essentially memories concerning the self (Conway, Singer, & Tagini, 2004). When stimuli are processed in a self-referential manner, it has been shown to increase memory performance (Glisky & Marquine, 2009; Gutchess, Kensinger, & Schacter, 2007; for a review, see Symons & Johnson, 1997) even for older adults (Leshikar & Duarte, 2014; Leshikar, Dulas, & Duarte, 2015). However, there is also evidence to suggest that there may be age-related differences in self-referential processing whereby older adults are more likely to process positive information in relation to themselves (Saverino, Grigg, Churchill, & Grady, 2014).

Self-referential processing is thought to depend upon the vmPFC (D'Argembeau et al., 2005; Johnson et al., 2002; Kelley et al., 2002; Rameson, Satpute, & Lieberman, 2010) and when individuals are asked to process information in a self-relevant manner, both younger and older adults show increased vmPFC activation (Gutchess et al., 2007). Importantly, the vmPFC has also been found to be more strongly activated among older adults for positive over negative images (Leclerc & Kensinger, 2008) leading some researchers to speculate that the positivity effect arises because compared to younger adults, older adults may be more likely to process positive information in relation to themselves (Leclerc & Kensinger, 2008).

Concerning our first empirical chapter, if it is the case that the positivity effect arises due to older adults being more likely to process positive information in a self-relevant manner, we may have expected older Leave voters to have demonstrated better memory performance compared to younger Leave voters. However, we did not find evidence to support this. Nevertheless, since flashbulb memories are inherently linked to ourselves and our identity (Wang & Aydin, 2017) it is likely that participants used self-referential processing to form their flashbulb memories. However, generally speaking it is typical for individuals to demonstrate a bias toward positive self-relevant information (Alicke & Govorun, 2005) which is reflected more widely in the autobiographical literature, in which there appears to be a memory recall bias for positive over negative life events (see Skowronski, 2011 for a review). Moreover, there is evidence to suggest that younger adults can replicate a similar positivity bias in memory to older adults when they are asked to process positive, self-relevant information (Leshikar et al., 2015). Therefore, when the information to be remembered is matched on positive valence and self-relevance, it might be the case that the positivity effect can be diminished.

With regards to our findings from our second study, if older adults' positivity effect was the consequence of increased self-referential processing for positive images, then we would have expected to have seen group differences in vmPFC activity. Yet, this was not the case. Although previous researchers found age-related changes in the processing of positive information whereby older adults exhibited greater vmPFC activity compared to younger adults (Leclerc & Kensinger, 2008), they did not investigate subsequent memory. As such, it makes it difficult to know whether self-referential processing in this context could have subsequently led to the positivity effect in memory. More recently, a study concentrating on the neural mechanisms responsible for self-referential and emotional processing among younger and older adults found that both younger and older adults recruited the vmPFC when processing self-relevant over other information (Daley et al., 2020). However, there were no memory benefits for positive self-relevant for older adults as might have been expected. Instead, only main effects of emotion and self-relevance were found. In other words, both younger and older adults showed similar patterns of vmPFC engagement when processing self-relevant information and similar patterns of memory performance.

More recently, an event-related potential (ERP) study investigating the relationship between the positivity effect and self-referential processing on the late positive potential (LPP) found a three way interaction between age, valence and self-relevance (Fields et al., 2021). Participants in the study were presented with verbal descriptions of scenarios that varied in self-relevance (self versus other) and valence (positive versus negative versus neutral) while electroencephalographic (EEG) activity was recorded. The results indicated that within the self-relevant condition, both younger and older adults showed the largest LPP to negative over positive and neutral stimuli but importantly, the difference between negative and positive LPPs was smaller among older adults. In other words, the older adults exhibited the positivity effect in the form of a reduced negativity bias for self-relevant information. Despite this however, there were no three-way interactions on subsequent memory recall or recognition tests. While older adults did demonstrate the positivity effect in memory recognition i.e. they remembered more positive compared to negative scenarios, they did not show enhanced memory for positive, self-relevant stimuli.

Taken together then, these findings cast doubt on whether self-referential processing, that often includes the activation of the vmPFC, is directly contributing to the positivity effect as has previously been proposed. As such, future research could expand on Field et al.'s (2021) work to examine the neural activity of the vmPFC more directly to determine whether the positivity effect is stronger under self-referential conditions and whether or not vmPFC activity during self-referential conditions can predict subsequent memory.

6.3.3 Considering the effects of stimulus novelty

Another appraisal dimension that may be relevant to our results in this thesis is novelty which also precedes emotion. Broadly speaking, the appraisal of novelty is an evaluation of whether the current event is in line with, or is different to what was expected (Scherer, 1988). As such, when something is appraised as 'novel', i.e. it is deemed to be unexpected, it often leads to feelings of surprise. Interestingly, in addition to responding to emotionally salient material, the amygdala is also thought to recognize stimulus novelty (Balderston, Schultz, & Helmstetter, 2011; Blackford, Buckholtz, Avery, & Zald, 2010; C. I. Wright, Wedig, Williams, Rauch, & Albert, 2006). In fact there is evidence to suggest that the amygdala does not necessarily serve to identify valence per se but instead detects stimuli that are salient or *novel* (Moriguchi et al., 2011). For example in one study, participants were presented with IAPS images that varied in terms of arousal and valence but also in novelty i.e. novel vs. familiar. The researchers found that the amygdala had larger peak responses and a longer time course of activation to the emotional novel images than familiar emotional images (Weierich, Wright, Negreira, Dickerson, & Barrett, 2010). As such, they concluded that novelty, in addition to valence and arousal, should be considered as an independent affective property.

The concept of novelty was also identified as an important factor in terms of flashbulb memory formation. For example Brown and Kulik (1977) emphasized the importance of novelty in forming flashbulb memories and suggested that in order for the "now print" mechanism to work, an event must firstly be appraised as *novel* which then subsequently leads to feelings of surprise. In turn, greater feelings of surprise are thought to lead to more intense emotional reactions (Chiew et al., 2021) which may help to sustain these memories in the long-term. However, within the flashbulb memory literature, there is evidence to suggest that feelings of surprise that are elicited by the appraisal of novelty, may differ depending on valence. In fact, some researchers have argued that the reason for the disproportionate number of negative to positive studied events is because surprising positive events are rarer (Kraha, Talarico, & Boals, 2014). Additionally, among the flashbulb memory studies that have examined positive and negative events, several have found that negative events are associated with higher levels of surprise (Berntsen & Thomsen, 2005; Kensinger, Krendl, &

Corkin, 2006; Liu, Ying, & Luo, 2012). Indeed, a recent flashbulb memory study investigating the United States' 2016 Presidential Election categorized participants into political groups (e.g. Clinton supporters versus Trump supporters versus third-party/non-voters) as well as anticipated outcome (surprised versus unsurprised participants; Chiew et al., 2021) and found that the intensity of negative emotion was driven by higher levels of surprise, though the same was not true for positive emotion. Collectively then, these findings suggest that perhaps we are less likely to appraise positive events as novel or unexpected.

Moreover, returning to Weierich et al.'s (2010) study, in which they found that the amygdala had larger peak responses to emotional novel images, they also found a significant novelty by valence interaction. More specifically, they found that amygdala activation was greater to novel negative images than to novel positive images. Therefore, across both autobiographical memory research and laboratory based research, there is reason to believe that negative stimuli may be considered to be more novel than positive stimuli which may help to explain why negative stimuli are remembered better over positive stimuli. When considering this finding in a practical sense, it is likely that we are exposed to more positive events and objects in daily life, meaning that negative stimuli seen in a laboratory setting may well be more novel or unexpected. For example, it is less likely that we encounter traumatic events on a day-to-day basis like witnessing a road traffic collision or being confronted by a weapon. Likewise, most people probably do not encounter a dangerous animal each day. Instead, it is more likely that, on a daily basis, we are exposed to items that we associate with positive affect such as appealing food items, a wedding/engagement ring or young children happily playing. Therefore, with this in mind and reflecting on our results in Study 2 (Chapter 4), this may help to explain why negative images were remembered better overall as they may have been considered more novel or salient in comparison to positive images. In other words, it may have been the case that negative images were less familiar and so required continuous evaluation and attentional resources which strengthened encoding, however it is important to note that our neural time course analysis does not support this theory. Instead, both younger and older adults showed similar levels of right and left amygdala activation to both negative > neutral images and positive > neutral images. Moreover, since we did not control for novelty or obtain ratings of surprise, we cannot be certain that this was indeed the case. Nevertheless, it highlights an important factor to consider when choosing emotional stimuli. Researchers should therefore consider the possibility that we may be exposed to more positive over negative stimuli in real-life settings that may then influence our interpretation of laboratory-based stimuli.

More importantly, the idea that novel negative stimuli may be remembered better does not explain the positivity effect we found in memory among older adults. In fact, while there is evidence to suggest that the processing of novel stimuli is preserved in aging (C. I. Wright et al., 2008; C. I. Wright et al., 2006), there is also research to suggest that there are age-related differences in novelty for positive versus negative stimuli. For example, one study found that older adults were more likely to interpret positive images as more familiar (or less novel) than younger adults (Moriguchi et al., 2011). Results like this therefore suggest that older adults' memory may instead benefit from familiar positive stimuli over unfamiliar negative stimuli. However, other researchers have speculated that when older adults are unsure about whether an image is 'old' or 'new' in a memory recognition test, they may rely on strategies that cause them to incorrectly identify novel positive stimuli as 'old' or familiar (Werheid et al., 2010). Therefore, rather than the positivity effect being a consequence of goal-directed attention during encoding, it could instead reflect a response bias in which older adults show a preference to endorse positive images as familiar (Spaniol, Voss, & Grady, 2008) or 'old'. However, the results of our experiment do not support this theory (see false alarm rate results in Chapter 4.8.2) but future studies should ensure that the positivity effect is not being driven by a response bias that is in favour of endorsing new positive images as ‘old’.

Reflecting on novelty in relation to our first study, it is possible that the appraised novelty of the EU Referendum was different to the appraised novelty of events that are wholly unexpected such as the 9/11 terrorist attack or the unexpected death of a well-known public figure. In our case, the EU Referendum was a political event that received a great deal of attention from the media before the results were officially announced and had associated political campaigns that ran for months beforehand. Essentially, it was not an event that came out of the blue and the results, one way or another, would have been anticipated or predicted. This may partly explain why we did not find support for negative emotion being associated with higher levels of surprise as has previously been found (Berntsen & Thomsen, 2005; Kensinger et al., 2006) as it could be the case that information in the run up to the official results gave people more certainty about the outcome (but see Chiew et al., 2021) which led to them feeling less surprised afterwards. It is also worth highlighting that our measures of surprise were retrospective and so may also not reflect the true levels of surprise the participants experienced at the exact moment they found out the results.

6.3.4 Broader implications

Overall, this thesis builds upon our current understanding of how emotion affects memory across the adult life-span and offers possible explanations as to why there are sometimes valence-related differences in memory and why aging is also associated with differences in emotional processing. However, understanding the age-related differences in emotional memory and well-being has important wider implications that extend beyond the research covered in this thesis. Some examples are briefly discussed below.

Firstly, by identifying the reasons for the positivity effect and the increase in emotional well-being with aging, it could be helpful in clinical settings. For example, identifying certain protective factors that could mitigate the risk for developing mood related disorders such as anxiety and depression could be beneficial in terms of treatment. In depression for example, patients typically demonstrate negative biases that are thought to be key features of the illness through behaviours such as sustained attention towards negative stimuli (Gotlib, Krasnoperova, Yue, & Joormann, 2004) that can then subsequently lead to preferential storage of negative information in memory (B. P. Bradley, Mogg, & Williams, 1995). Therefore, if it is the case that the positivity effect and better emotional well-being in older adults stems from a shift in time perspective which encourages them to concentrate on short-term goals that maximize positive affect, then current methods of therapy could exploit this finding. For example, clinicians could implement strategies in treatment to encourage adults with depression to concentrate more on short-term achievable goals that can influence and improve current mood. Alternatively, if it is the case that the positivity effect is the consequence of diminished responses to arousing stimuli, then targeting ways to reduce younger adults responses to highly arousing information may also be an option.

Secondly, due to the medical advances across the world, many countries are seeing a rise in their aging populations. In fact, it is predicted that by 2050, the percentage of the world population over the age of 65 will increase to 15.9% from its current estimated figure of 9.3% (United Nations Department of Economic and Social Affairs, 2019). This means that there will inevitably be an increase in the prevalence of age-related diseases, including memory related illnesses such as dementia. While the purpose of this thesis did not intend to explore memory loss, one of the theories explaining the age-related differences in emotional memory proposes that it is a consequence of neural decline. Therefore, continuing to understand how emotional memories are formed among younger adults and ‘healthy’ older adults would allow us to detect behavioural and/or neural patterns that could indicate memory vulnerabilities in the aged. In other words, it will be important to gain a solid understanding of what constitutes healthy memory decline for emotional material in aging so that abnormal memory decline can be detected more easily.

Thirdly, recalling emotional events can also have important real-life implications in certain settings, for example when providing an eyewitness statement for a crime or an accident. In the Introduction, it was highlighted that emotional arousal can have both enhancing and impairing effects on memory, for example arousal can lead to better memory for the central information over peripheral information. However, the results of this thesis and the findings from past experiments suggest that age-related differences in emotional memory may also be an important factor to consider too. If the proportion of our world population over the age of 65 is predicted to increase with many older adults expected to live longer given the advances in medical treatment, then deepening our understanding of older adults' ability to recall memories relating to a crime or an accident will have important implications in many future legal settings. Generally speaking however, older adults' memory is considered to be impaired compared to younger adults and there is evidence to suggest that the elderly are considered to be unreliable eyewitnesses by law enforcement officials (A. M. Wright & Holliday, 2005). However, the research discussed in this thesis suggests that older adults still benefit from emotional memory enhancement and therefore may not be as unreliable as one might first assume. Therefore, if crimes and/or accidents are accompanied by increased levels of emotional arousal, then the memory of older adults may actually be improved. As such, aging stereotypes prevalent within law-enforcement and legal settings surrounding older adults' memory ability should be reconsidered. Nevertheless, the findings in this thesis do highlight that younger and older adults may be more susceptible to different emotional biases in memory recall, particularly concerning valence which may be important to acknowledge in such legal settings. Consequently, deepening our understanding in this area would be beneficial so that lawyers can more accurately convey the limitations of older adult's eyewitness memories and highlight the conditions under which memory performance may be better or worse.

6.4 Conclusion

In summary, there are three main conclusions that can be drawn from the findings presented in this thesis. Firstly, consistent with previous literature, emotional events, irrespective of valence can be remembered long-term with high levels of confidence, vividness and consistency. However, valence can have differential effects on the subjective and objective memory measures in both the short and long-term and negative emotion specifically is associated with increased memory performance. As such, it provides evidence that valence, in addition to arousal, can have differential effects on memory. Second, older adults exhibit differences in the time course of prefrontal activation during emotional processing that may reflect cognitive control efforts which contribute to the age-related differences frequently seen in memory i.e. the *positivity effect*. Third, although age-related differences seen in the laboratory may be a consequence of older adults prioritising emotion-related goals due to a limited perception of time left in life, better emotional well-being is not necessarily driven by the same factors. Instead, emotional well-being and emotional processing evidenced in the laboratory could result from two different pathways (an indirect pathway and a direct pathway) through which future time perspective can influence emotional processing.

Overall, this thesis has concentrated mainly on the relationship between emotion and memory across the adult life-span and further considered the relationship between emotional memory and emotional well-being in an attempt to elucidate some of the inconsistencies within the previous literature. Moreover, it sought to bridge the gap between autobiographical memories, memories formed within the laboratory and emotional well-being to further understand age-related differences in emotional processing across different contexts. It has identified important limitations of both the current and previous research and highlighted possible avenues for future exploration. Likewise, it has drawn attention to the scientific challenges associated with measuring and defining emotion and demonstrated that understanding age-related differences in emotional processing remains a fruitful area for scientific research with many questions still remaining unanswered.

6.5 References

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7. Appendices

Appendix A

List of survey questions administered in Study 1 (Chapter 3).

Survey 1.

1.1 Survey entry questions

1) Please enter your age.

2) Please indicate your nationality.

3) Where do you currently reside?

( ) United Kingdom / ( ) United States / ( ) Other: ___

4) Please enter your Prolific ID.

5) Please follow the instructions from the consent form and fill in the box below.

1.2 EU referendum - How you voted and why

6) Were you eligible to vote in the 2016 UK's EU referendum?

( ) Yes / ( ) No

7) How did you vote?

( ) To remain in the EU / ( ) To leave the EU / ( ) I was eligible but I did not vote

8) Please indicate how you voted.

( ) I voted on the day at a polling station. / ( ) I voted by post. / ( ) I voted by proxy.

9) What was your main reason for voting or not voting? Briefly describe in one sentence below.

10) Do you regret your voting choice? *Please answer even if you did not vote.*

( ) Not at all *( ) Very slightly* *( ) To some degree* *( ) A great deal*

11) Irrespective of what side you voted for, please indicate how influential the following factors were in your voting decision. *(1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) Ability to travel/work/study in EU countries / b) EU Laws and legislation

c) Economy / d) Education / e) Fear of uncertainty / f) Immigration / g) NHS/ Health Care

12) Please answer the following questions using the scale below. (*1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) How vividly do you remember the time you voted?

b) How confident were you that your choice was right at the time?

c) How confident were you that your party would win the campaign?

13) How strongly did you feel emotion when you voted*? (1. Not at all to 6. Very strongly)*

14) Please indicate how strongly you felt each of the following emotions
(Happy/Proud/Sad/Anxious; 1. 'Not at all' to **7.** *'Very strongly')*

1.3 EU referendum - Memory for the results

15) How vividly do you remember the time you became aware of the referendum outcome? *(1. Not very to 7. Extremely)*

16) What time was it when you found out the results?

17) How did you learn the outcome? Please use the box below to give us a little bit more detail about the source (such as the name of the TV programme you watched; the name of the website you checked). *(TV, Internet, Friends/ Family, Newspaper, Radio, Other)*

18) Where were you when you found out the results? **Please describe in one sentence and be specific.**

19) Who else was there when you found out? **Please describe in one sentence and be specific.**

20) What were you doing beforehand?

21) What did you do immediately after finding out the results?

22) How strongly did you feel emotion when you found out the results? *(1. Not at all to 6. Very strongly)*

23) How strongly did you feel the following emotions when you found out the results? (*Angry/Surprise/Sad/Happy/Anxious/Proud;* **1**. *Not at all to* **7**. *Very strongly)*

1.4 Your current feelings about the EU referendum result

24) How important are the referendum results to you? *(1. Not important to 7. Extremely important)*

25) Please indicate your **current** feelings using the scale below. *(1. Strongly disagree to 7. Strongly agree)*

    a. At this moment, I believe that the UK should leave the EU
    b. I expect to have personal benefits from the referendum results.
    c. At this moment, I am satisfied with the referendum results.
    d. I expect to suffer personal loss due to the referendum results
    e. I should have done more to help with my campaign

26) How strongly do you *currently* feel emotion when you think of the referendum? (**1**. *Not at all to* **7**. *Very strongly)*

27) How strongly do you feel the following emotions when you think of the referendum now?

    (Angry/Surprise/Sad/Happy/Anxious/Proud; **1**. *Not at all to* **7**. *Very strongly)*

28) How positive or negative do you feel about the following*:* (*Negative* **= -3** *and Positive =* **+3***)*

    a. UK / b. EU

29) In the past week.. *Rarely or none of the time (Less than 1 day), Some (1 - 2 days), Occasionally (3 - 4 days), Most of the time (5 - 6 days), Daily*

a. How closely have you followed the media coverage of the referendum result?
b. Have you thought about the referendum since finding out the results?
c. Have you spent on the internet reading the latest news about the referendum?
d. Have you talked about the referendum with your friends/family and colleagues?

1.5 Demographics

30) Please indicate your gender

() Male / () Female

31) Please select your race. If it is not listed, please specify using 'Other'.

( ) American Indian/Alaska Native / ( ) Asian / ( ) Black / ( ) Biracial/ Mixed /

( ) Black/African-American / ( ) Native Hawaiian or Other Pacific Islander / ( ) White /

( ) Prefer not to say / ( ) Other: _________

32) What is your religion? If other, please specify.

( ) Buddhism / ( ) Christianity / ( ) Hinduism / ( ) Islam / ( ) Judaism / ( ) Sikhism /

( ) None / ( ) Prefer not to say / ( ) Other / Comments:

33) What is your political affiliation? If other, please specify.

( ) Conservative / ( ) Labour / ( ) Scottish National Party / ( ) Liberal Democrats /

( ) UKIP / ( ) Republican (USA) / ( ) Democratic (USA) / ( ) None / ( ) Prefer not to say

( ) Other / Comments:

34) Please select your highest level of education. (On the left is UK education / on the right is US education).

( ) Less than secondary school / Less than high school / ( ) GCSE's/ O-Levels / High School / ( ) AS-A level (or College equivalent)/ SATs or graduated high school /

( ) Bachelor's degree or equivalent/ University degree / ( ) Master's degree /

( ) Doctorate (Ph.D.) or M.D. and above / ( ) Prefer not to say

35) What is your occupation?

36) Please rate the following statements? *(1. Strongly disagree to 7. Strongly agree)*

I am satisfied with my life.

37) How much do you think you will be satisfied with your life as a whole in THREE MONTHS from now? *(1. Very Dissatisfied to 5. Very Satisfied)*

38) Please let us know if you have participated in this study before or if you encountered any technical issues.

[ ] I have participated before / [ ] I have not participated before

[ ] Other - For technical issues: ______________________

39) Would you like to be contacted again for the follow-up studies? *Each will take around 10 minutes and we will pay the same rate.*

( ) Yes / ( ) No

40) Lastly we would like you to answer a question to ensure that you paid attention to our task. In the following question, please type 'NA' in the box rather than selecting any given options. Which of these activities do you engage in regularly?

[ ] Playing sports / [ ] Watching TV / [ ] Cooking / [ ] Reading / [ ] Listening to music

[ ] Other - Write In: ____

Survey 2.

2.1 Study Information

1) Please enter your Unique ID / Prolific ID.

2) Please follow the instructions from the consent form and fill in the box below.

2.2 EU referendum - How you voted and why

3) Were you eligible to vote in the UK's EU referendum?

( ) Yes / ( ) No

4) We may have asked this previously but please select which side you voted for.

( ) To Leave the EU / ( ) To Remain in the EU / ( ) I was eligible but I did not vote

5) We may have asked this before, but please indicate how you voted.

( ) I voted on the day at a polling station. / ( ) I voted by post. ( ) I voted by proxy.

6) What was your main reason for voting or not voting? Briefly describe in one sentence below.

7) How influential were the following factors in your voting decision. *(1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) Ability to travel/work/study in EU countries / b) EU Laws and legislation

c) Economy / d) Education / e) Fear of uncertainty / f) Immigration / g) NHS/ Health Care

8) Please answer the following questions using the scale below. (*1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) How vividly do you remember the time you voted?

b) How confident were you that your choice was right at the time?

c) How confident were you that your party would win the campaign?

9) How strongly did you feel emotion when you voted? *(1. Not at all to 6. Very strongly)*

10) When you voted, how strongly did you feel each of the following emotions *(Happy/Proud/Sad/Anxious; 1. 'Not at all' to* **7.** *'Very strongly')*

2.3 EU referendum - Memory for the results

11) How vividly do you remember the time you became aware of the referendum outcome? *(1. Not very to 7. Extremely)*

12) What time was it when you found out the results?

13) How did you learn the outcome? Please use the box below to give us a little bit more detail about the source (such as the name of the TV programme you watched; the name of the website you checked). *(TV, Internet, Friends/ Family, Newspaper, Radio, Other)*

14) Where were you when you found out the results? **Please describe in one sentence and be specific.**

15) Who else was there when you found out? **Please describe in one sentence and be specific.**

16) What were you doing beforehand?

17) What did you do immediately after finding out the results?

18) How strongly did you feel emotion when you found out the results? *(1. Not at all to 6. Very strongly)*

19) How strongly did you feel the following emotions when you found out the results? (*Angry/Surprise/Sad/Happy/Anxious/Proud;* **1**. *Not at all to* **7.** *Very strongly)*

21) During the week after you found out the results... *Rarely or none of the time (Less than 1 day), Some (1 - 2 days), Occasionally (3 - 4 days), Most of the time (5 - 6 days), Daily*

a. How closely did you follow the media coverage of the referendum result?

b. Did you think about the referendum since finding out the results?

c. Did you spend on the internet reading the latest news about the referendum?

d. Did you talk about the referendum with your friends/family and colleagues?

22) How confident are you in your **overall recollection** of when you found out the referendum results? *(1. Not at all – 7. Extremely)*

2.4 Your current feelings about the EU referendum result

23**) In the past 3 months.** Using the scale below, please select the most appropriate answer **(1. Very little to 7. A great deal).**

a. How closely have you followed the media coverage of the referendum result?

b. Have you thought about the referendum since finding out the results?

c. Have you spent on the internet reading the latest news about the referendum?

d. Have you talked about the referendum with your friends/family and colleagues?

24) How much do you think your memory for the results of the EU referendum has been influenced by the following factors? ***(1. Very little to 7. A great deal).***

a. Friends / b. The Media / c. My Emotions

25) After the results, did you regret your voting choice? *Please answer even if you did not vote.*

( ) Not at all ( ) Very slightly ( ) To some degree ( ) A great deal

26) If you had the choice to vote again, would you vote differently? If yes, please briefly explain why.

( ) No / ( ) Yes: _______

27) How important are the referendum results to you? *(1. Not important to 7. Extremely important)*

28) Please indicate your **current** feelings using the scale below. *(1. Strongly disagree to 7. Strongly agree)*

a. At this moment, I believe that the UK should leave the EU
b. At this moment, I am satisfied with the referendum results.
c. I expect to have personal benefits from the referendum results.
d. I expect to suffer personal loss due to the referendum results
e. I should have done more to help with my campaign

29) How strongly do you *currently* feel emotion when you think of the referendum? *(1. Not at all to 6. Very strongly)*

30) How strongly do you feel the following emotions when you think of the referendum now? *(Angry/Surprise/Sad/Happy/Anxious/Proud; **1.** Not at all to **7.** Very strongly)*

31) Has your life been affected/ inconvenienced in any way as a result of the decision to leave the EU? If yes, please briefly explain how.

( ) No / ( ) Yes: _____

32) Since the EU Referendum results has your life...?

( ) got better / ( ) got worse / ( ) stayed the same

33) How positive or negative do you feel about the following: (*Negative* = **-3** and *Positive* = **+3**)

a. UK / b. EU

2.5 Demographics

34) Please select your date of birth.

35) Please remind us of your gender.

( ) Male / ( ) Female

36) Please select your time zone. *If other, please specify.*

( ) Greenwich Mean Time Zone / ( ) Central European Time Zone / ( ) Eastern European Time Zone / ( ) Eastern Standard Time (EST) / ( ) Central Standard Time /

( ) Mountain Standard Time / ( ) Pacific Standard Time / ( ) Other: _____

37) Please rate the following statement. **I am satisfied with my life. (1.** *Strongly disagree to 7. Strongly agree).*

38) How much do you think you will be satisfied with your life as a whole in THREE MONTHS from now? *1 Very Dissatisfied to 5 Very Satisfied.*

2.6 Follow-Up Questions

39) Please let us know if you have participated in this version of the study before (EU Referendum - Follow-Up 1) or if you encountered any technical issues.

[ ] I have participated in the follow-up session before / [ ] I have not participated in the follow-up session before [ ] I did not take part in the initial survey [ ] Other - For technical issues: ____

40) Would you like to be contacted again for the follow-up studies? *Each will take around 10 minutes and we will pay the same rate.*

( ) Yes / ( ) No

41) Lastly we would like you to answer a question to ensure that you paid attention to our task. In the following question, please type **1234** in the '*Other'* box rather than answering the question below. If the words were listed in alphabetical order, which word would come first?

( ) Apple / ( ) Animal / ( ) Alien / ( ) Afraid / ( ) Avalanche / ( ) Atlanta / ( ) Other: ______________________

Survey 3.

3.1 Study Information

1) Please enter your Unique ID / Prolific ID.

2) Please follow the instructions from the consent form and fill in the box below.

3.2 A bit about you!

3) What is your Nationality?

4) If your nationality was not listed, please tell us your nationality using the box below:

5) Where do you currently reside?

( ) UK / ( ) US / ( ) Other : __________________

3.3 EU referendum - How you voted and why.

6) Were you eligible to vote in the UK's EU referendum?

( ) Yes / ( ) No

7) Please select which side you voted for.

( ) To leave the EU / ( ) To remain in the EU / ( ) I was eligible but I did not vote

8) Please indicate how you voted.

( ) I voted on the day at a polling station. / ( ) I voted by post. / ( ) I voted via proxy.

9) Please remember your main reason for voting or not voting at the time of the referendum. Briefly describe in one sentence below.

10) If you had been given the opportunity to vote in the UK's EU Referendum, how would you have voted?

( ) To 'Leave' the EU / ( ) To 'Remain' in the EU / ( ) I would not have voted /

( ) I don't know

11) Please briefly explain the reason for your answer to the previous question.

3.4 How you voted and why

12) Please remember how influential the following factors were in your voting decision.

(1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)

a) Ability to travel/work/study in EU countries / b) EU Laws and legislation

c) Economy / d) Education / e) Fear of uncertainty / f) Immigration / g) NHS/ Health Care

13) Please answer the following questions using the scale below. *(1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) How vividly do you remember the time you voted?

b) How confident were you that your choice was right at the time?

c) How confident were you that your party would win the campaign?

14) How strongly did you feel emotion when you voted? *(1. Not at all to 6. Very strongly)*

15) When you voted, how strongly did you feel each of the following emotions *(Happy/Proud/Sad/Anxious; 1. 'Not at all' to* **7.** *'Very strongly')*

3.5 EU referendum - Memory for the results

16) How vividly do you remember the time you became aware of the referendum outcome? *(1. Not very to 7. Extremely)*

17) What time was it when you found out the results?

18) How confident are you in your recollection of **what time it was when you found out the results**? *(1. Not very to 7. Extremely)*

19) How did you learn the outcome? Please use the box below to give us a little bit more detail about the source (such as the name of the TV programme you watched; the name of the website you checked). *(TV, Internet, Friends/ Family, Newspaper, Radio, Other)*

20) Where were you when you found out the results? **Please describe in one sentence and be specific.**

21) Who else was there when you found out? **Please describe in one sentence and be specific.**

22) What were you doing beforehand?

23) What did you do immediately after finding out the results?

24) How strongly did you feel emotion when you found out the results? *(1. Not at all to 6. Very strongly)*

25) How strongly did you feel the following emotions when you found out the results? (*Angry/Surprise/Sad/Happy/Anxious/Proud;* **1.** *Not at all to* **7**. *Very strongly)*

26) During the week after you found out the results... *Rarely or none of the time (Less than 1 day), Some (1 - 2 days), Occasionally (3 - 4 days), Most of the time (5 - 6 days), Daily*

a. How closely did you follow the media coverage of the referendum result?
b. Did you think about the referendum since finding out the results?
c. Did you spend on the internet reading the latest news about the referendum?
d. Did you talk about the referendum with your friends/family and colleagues?

27) How confident are you in your **overall recollection** of when you found out the referendum results? *(1. Not at all to 7. Extremely)*

28) After finding out the results of the EU Referendum, did you expect Article 50 to be triggered within a year? *If yes, please briefly explain when you thought Article 50 would be triggered.*

( ) Yes: ____

( ) No, not so soon but I expected it to happen at some point.

( ) No, I did not think it would ever be triggered

( ) Other: ____

( ) I wasn't sure/ had not heard of Article 50 at that point

3.6 Your current feelings about the EU referendum result

29) **In the past 9 months..** Using the scale below, please select the most appropriate answer **(1. Very little to 7. A great deal).**

a. How often have you followed the media coverage of the referendum result?
b. Have often have you thought about the referendum since finding out the results?
c. How often have you spent on the internet reading the latest news about the referendum?
d. How often have you talked about the referendum with your friends/family and colleagues?

30) How much do you think your memory for the results of the EU referendum has been influenced by the following factors? ***(1. Very little to 7. A great deal).***

a. Friends / b. The Media / c. My Emotions

31) After the results, did you regret your voting choice? *Please answer even if you did not vote.*

( ) Not at all ( ) Very slightly ( ) To some degree ( ) A great deal

32) If you had the choice to vote again, would you vote differently? If yes, please briefly explain why.

( ) No / ( ) Yes: ____

33) How important are the referendum results to you? *(1. Not important to 7. Extremely important)*

34) Please indicate your **current** feelings using the scale below. *(1. Strongly disagree to 7. Strongly agree).*

f. At this moment, I believe that the UK should leave the EU
g. At this moment, I am satisfied with the referendum results.
h. I expect to have personal benefits from the referendum results.
i. I expect to suffer personal loss due to the referendum results
j. I should have done more to help with my campaign

35) How strongly do you *currently* feel emotion when you think of the referendum? (*1. Not at all to 6. Very strongly)*

36) How strongly do you feel the following emotions when you think of the referendum now? *(Angry/Surprise/Sad/Happy/Anxious/Proud;* **1**. *Not at all to* **7**. *Very strongly)*

37) Has your life been affected/ inconvenienced in any way as a result of the decision to leave the EU? If yes, please briefly explain how.

( ) No / ( ) Yes: ____

38) Since the EU Referendum results has your life...?

( ) got worse / ( ) stayed the same / ( ) got better

39) How positive or negative do you feel about the following: (*Negative* = **-3** and *Positive* = **+3**)

a. UK / b. EU

3.7 Article 50

40) How strongly did you feel emotion when Article 50 was triggered? (*1. Not at all to 6. Very strongly)*

41) How strongly did you feel the following emotions when Article 50 was triggered? *(Angry/Surprise/Sad/Happy/Anxious/Proud;* **1**. *Not at all to* **7**. *Very strongly)*

42) How much do you agree with the following statements?

a. The UK government has well thought out plans about the negotiation with EU

b. The House of Commons should have played more of a role in outlining the negotiation plans with EU.
c. The House of Lords should have played more of a role in outlining the negotiation plans with EU.
d. In general, I feel confident the current UK government will successfully conclude the negotiation with EU with good deals for the UK.
e. I am not concerned about the final deal with EU as long as the UK leaves from EU.

43) In your opinion, which of the following should be prioritised in the negotiation with EU? *(**1.** "Low Priority" to **7**. "High Priority").*

a. Rights of British citizens who currently live and/or work in EU countries to remain in EU countries
b. Border between Northern Ireland and Ireland
c. Trade deals with EU countries Control of new immigration from EU countries
d. Rights of EU citizens who currently live and/or work in the UK to remain in the UK
e. Ensuring London can still be a financial centre in Europe.

44) What is your main concern about the negotiation with EU? Please describe in a sentence below.

45) In two year's time when the UK leaves the EU, how satisfied do you think you will be with your life? *1 Very Dissatisfied to 5 Very Satisfied.*45)

46) In two year's time when the UK leaves the EU, how positive or negative do you think you will feel towards...

a. UK / b. EU

3.8 US Election

47) Were you eligible to vote in the recent US Presidential Election?

( ) Yes / ( ) No

48) Please indicate how you voted in the US Presidential Election.

( ) Republican Candidate - Donald Trump / ( ) Democratic Candidate - Hilary Clinton / ( ) Other Party: _______ / ( ) I was eligible but I did not vote / ( ) Prefer not to say

49) How strongly do you *currently* feel emotion when you think of the results of the recent US Presidential Election? *(1. Not at all to 6. Very strongly)*

3.9 Demographics

50) Please enter your age

51) Please select your sex

( ) Male / ( ) Female

52) Please select your race. If it is not listed, please specify using 'Other'.

( ) American Indian/Alaska Native / ( ) Asian / ( ) Black / ( ) Biracial/ Mixed / ( ) Black/African-American / ( ) Native Hawaiian or Other Pacific Islander / ( ) White /

( ) Prefer not to say / ( ) Other: __________

53) What is your religion?

( ) Buddhism / ( ) Christianity / ( ) Hinduism / ( ) Islam / ( ) Judaism / ( ) Sikhism /

( ) None / ( ) Prefer not to say / ( ) Other: ________

54) What is your political affiliation? If other, please specify.

( ) Conservative / ( ) Labour / ( ) Scottish National Party / ( ) Liberal Democrats

( ) UKIP / ( ) Republican (USA) / ( ) Democratic (USA) / ( ) None / ( ) Prefer not to say ( ) Other: ________

55) What's your highest level of education?

( ) Less than secondary school / Less than high school / ( ) GCSE's/ O-Levels / High School / ( ) AS-A level (or College equivalent)/ SATs or graduated high school / ( ) Bachelor's degree or equivalent/ University degree / ( ) Master's degree / ( ) Doctorate (Ph.D.) or M.D. and above / ( ) Prefer not to say

56) What is your occupation?

57) Please select your timezone. *If other, please specify.*

( ) Greenwich Mean Time Zone / ( ) Central European Time Zone / ( ) Eastern European Time Zone / ( ) Eastern Standard Time (EST) / ( ) Central Standard Time /

( ) Mountain Standard Time / ( ) Pacific Standard Time / ( ) Other: _____

58) Please rate the following statement. **I am satisfied with my life.** *(1. Strongly disagree to 7. Strongly agree)*

59) How much do you think you will be satisfied with your life as a whole in SIX MONTHS from now? *(1. Very Dissatisfied to 5. Very Satisfied)*

3.10 Contact details

60) Please let us know if you have participated in *a* version of this study before or if you encountered any technical issues.

[ ] I have participated in this study before / [ ] I have not participated before/ [ ] Other - For technical issues:____

61) Are you happy to be invited to the final follow-up survey?

( ) Yes I am happy to be invited / ( ) Yes I am happy but wish to update my email address: / ( ) No I would not like to be invited back

62) Finally, we have one last question to determine if you have been paying attention. To show that you have read the information above, please ignore the statement below and select '4' rather than any of the odd numbers.
Please select all of the odd numbers below:

[ ] 1 /[ ] 2 /[ ] 3 /[ ] 4 /[ ] 5 /[ ] 6 /[ ] 7 /[ ] 8 /[ ] 9 /[ ] 10 /

Survey 4.

4.1 Study Information

---

1) Please enter your Unique ID / Prolific ID.

2) Please follow the instructions from the consent form and fill in the box below.

4.2 A bit about you!

3) What is your Nationality?

4) If your nationality was not listed, please tell us your nationality using the box below:

5) Where do you currently reside?

( ) UK / ( ) US / ( ) Other: __________

4.3 EU referendum - How you voted and why.

6) Were you eligible to vote in the UK's EU referendum?

( ) Yes / ( ) No

7) Please select which side you voted for.

( ) To leave the EU / ( ) To remain in the EU / ( ) I was eligible but I did not vote

8) Please indicate how you voted.

( ) I voted on the day at a polling station. / ( ) I voted by post. / ( ) I voted via proxy.

9) Please remember your main reason for voting or not voting at the time of the referendum. Briefly describe in one sentence below.

10) If you had been given the opportunity to vote in the UK's EU Referendum, how would you have voted?

( ) To 'Leave' the EU / ( ) To 'Remain' in the EU / ( ) I would not have voted / ( ) I don't know

11) Please briefly explain the reason for your answer to the previous question.

4.4 How you voted and why

12) Please remember how influential the following factors were in your voting decision. *(1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) Ability to travel/work/study in EU countries / b) EU Laws and legislation

c) Economy / d) Education / e) Fear of uncertainty / f) Immigration / g) NHS/ Health Care

13) Please answer the following questions using the scale below. *(1. Not at all, 2. Slightly, 3. Somewhat, 4. Very, 5. Extremely)*

a) How vividly do you remember the time you voted?

b) How confident were you that your choice was right at the time?

c) How confident were you that your party would win the campaign?

14) How strongly did you feel emotion when you voted? *(1. Not at all to 6. Very strongly)*

15) When you voted, how strongly did you feel each of the following emotions *(Happy/Proud/Sad/Anxious; 1. 'Not at all' to* **7.** *'Very strongly')*

4.5 EU referendum - Memory for the results

16) How vividly do you remember the time you became aware of the referendum outcome? *(1. Not very to 7. Extremely)*

17) What time was it when you found out the results?

18) How confident are you in your recollection of **what time it was when you found out the results**? (*1. Not very to 7. Extremely)*

19) How did you learn the outcome? Please use the box below to give us a little bit more detail about the source (such as the name of the TV programme you watched; the name of the website you checked). *(TV, Internet, Friends/ Family, Newspaper, Radio, Other)*

20) Where were you when you found out the results? **Please describe in one sentence and be specific.**

21) Who else was there when you found out? **Please describe in one sentence and be specific.**

22) What were you doing beforehand?

23) What did you do immediately after finding out the results?

24) How strongly did you feel emotion when you found out the results? *(1. Not at all to 6. Very strongly)*

25) How strongly did you feel the following emotions when you found out the results? (*Angry/Surprise/Sad/Happy/Anxious/Proud;* **1**. *Not at all to* **7**. *Very strongly)*

26) During the week after you found out the results... *Rarely or none of the time (Less than 1 day), Some (1 - 2 days), Occasionally (3 - 4 days), Most of the time (5 - 6 days), Daily*

a. How closely did you follow the media coverage of the referendum result?

b. Did you think about the referendum since finding out the results?

c. Did you spend on the internet reading the latest news about the referendum?

d. Did you talk about the referendum with your friends/family and colleagues?

27) How confident are you in your **overall recollection** of when you found out the referendum results? *(1. Not at all to 7. Extremely)*

28) After finding out the results of the EU Referendum, did you expect Article 50 to be triggered within a year? *If yes, please briefly explain when you thought Article 50 would be triggered.*

( ) Yes: ____

( ) No, not so soon but I expected it to happen at some point.

( ) No, I did not think it would ever be triggered

( ) Other: ____

( ) I wasn't sure/ had not heard of Article 50 at that point

4.6 Your current feelings about the EU referendum result

29) **In the past 16 months..** Using the scale below, please select the most appropriate answer ***(1. Very little to 7. A great deal).***

e. How often have you followed the media coverage of the referendum result?
f. Have often have you thought about the referendum since finding out the results?
g. How often have you spent on the internet reading the latest news about the referendum?
h. How often have you talked about the referendum with your friends/family and colleagues?

30) How much do you think your memory for the results of the EU referendum has been influenced by the following factors? ***(1. Very little to 7. A great deal).***

a. Friends / b. The Media / c. My Emotions

31) After the results, did you regret your voting choice? *Please answer even if you did not vote.*

( ) Not at all *( ) Very slightly* *( ) To some degree* *( ) A great deal*

32) If you had the choice to vote again, would you vote differently? If yes, please briefly explain why.

( ) No / ( ) Yes: ______________________________

33) How important are the referendum results to you? *(1. Not important to 7. Extremely important)*

34) Please indicate your **current** feelings using the scale below. *(1. Strongly disagree to 7. Strongly agree).*

a. At this moment, I believe that the UK should leave the EU

b. At this moment, I am satisfied with the referendum results.

c. I expect to have personal benefits from the referendum results.

d. I expect to suffer personal loss due to the referendum results

e. I should have done more to help with my campaign

35) How strongly do you *currently* feel emotion when you think of the referendum? (*1. Not at all to 6. Very strongly)*

36) How strongly do you feel the following emotions when you think of the referendum now? (**1** = *Not at all* to **7** = *Very strongly)*

a. Angry / b. Surprise / c. Sad / d. Happy / e. Anxious / f. Proud

37) Has your life been affected/ inconvenienced in any way as a result of the decision to leave the EU? If yes, please briefly explain how.

( ) No / ( ) Yes: ________________________________

38) Since the EU Referendum results has your life...?

( ) got worse / ( ) stayed the same / ( ) got better

39) How positive or negative do you feel about the following: (*Negative* = **-3** and *Positive* = **+3**)

a. UK / b. EU

4.7 Article 50

40) How strongly did you feel emotion when Article 50 was triggered? (*1. Not at all to 6. Very strongly)*

41) How strongly did you feel the following emotions when Article 50 was triggered? *(Angry/Surprise/Sad/Happy/Anxious/Proud;* **1**. *Not at all to* **7**. *Very strongly)*

42) How much do you agree with the following statements?

f. The UK government has well thought out plans about the negotiation with EU
g. The House of Commons should have played more of a role in outlining the negotiation plans with EU.
h. The House of Lords should have played more of a role in outlining the negotiation plans with EU.
i. In general, I feel confident the current UK government will successfully conclude the negotiation with EU with good deals for the UK.
j. I am not concerned about the final deal with EU as long as the UK leaves from EU.

43) In your opinion, which of the following should be prioritised in the negotiation with EU? *(***1.** *"Low Priority" to* **7**. *"High Priority").*

Rights of British citizens who currently live and/or work in EU countries to remain in EU countries

f. Border between Northern Ireland and Ireland
g. Trade deals with EU countries Control of new immigration from EU countries
h. Rights of EU citizens who currently live and/or work in the UK to remain in the UK
i. Ensuring London can still be a financial centre in Europe.

44) What is your main concern about the negotiation with EU? Please describe in a sentence below.

45) In two year's time when the UK leaves the EU, how satisfied do you think you will be with your life? *1 Very Dissatisfied to 5 Very Satisfied.*

46) In two year's time when the UK leaves the EU, how positive or negative do you think you will feel towards...

b. UK
c. EU

4.8 The UK's General Election 2017

47) In the General Election (2017) held earlier this year, who did you vote for?

( ) Conservative / ( ) Labour / ( ) Liberal Democrats / ( ) Green Party /

( ) UKIP / ( ) Prefer not to say / ( ) I did not vote / ( ) Other: ____________

48) Please provide a brief reason for your voting choice in the UK's general election 2017.

4.9 US Election

49) Were you eligible to vote in the recent US Presidential Election held in 2016 in which Donald Trump became president of the United States?

( ) Yes / ( ) No

50) Please indicate how you voted in the US Presidential Election.

( ) Republican Candidate - Donald Trump

( ) Democratic Candidate - Hilary Clinton

( ) Other Party: : ____

( ) I was eligible but I did not vote

( ) Prefer not to say

51) How strongly *did you* feel emotion when you learnt the results of the US Presidential Election? *(1. Not at all to 6. Very strongly)*

52) How strongly do you *currently* feel emotion when you think of the results of the recent US Presidential Election? *(1. Not at all to 6. Very strongly)*

4.10 Demographics

53) Please enter your age

54) Please select your sex

( ) Male / ( ) Female

55) Please select your race. If it is not listed, please specify using 'Other'.

( ) American Indian/Alaska Native / ( ) Asian / ( ) Black / ( ) Biracial/ Mixed / ( ) Black/African-American / ( ) Native Hawaiian or Other Pacific Islander / ( ) White /

( ) Prefer not to say / ( ) Other: __________

56) What is your religion?

( ) Buddhism / ( ) Christianity / ( ) Hinduism / ( ) Islam / ( ) Judaism / ( ) Sikhism /

( ) None / ( ) Prefer not to say / ( ) Other: ________

57) What is your political affiliation? If other, please specify.

( ) Conservative / ( ) Labour / ( ) Scottish National Party / ( ) Liberal Democrats

( ) UKIP / ( ) Republican (USA) / ( ) Democratic (USA) / ( ) None / ( ) Prefer not to say ( ) Other: ________

58) What's your highest level of education?

( ) Less than secondary school / Less than high school / ( ) GCSE's/ O-Levels / High School / ( ) AS-A level (or College equivalent)/ SATs or graduated high school / ( ) Bachelor's degree or equivalent/ University degree / ( ) Master's degree / ( ) Doctorate (Ph.D.) or M.D. and above / ( ) Prefer not to say

59) What is your occupation?

60) Please rate the following statement. **I am satisfied with my life.** *(1. Strongly disagree to 7. Strongly agree)*

61) How much do you think you will be satisfied with your life as a whole in TWO YEARS from now? *(1. Very Dissatisfied to 5. Very Satisfied)*

4.11 Contact details

62) Please let us know if you encountered any technical issues.

[ ] Other - For technical issues: ____

63) Although this is our final follow-up study for now, we may decide to run a similar study relating to the EU referendum in the future. Would you be happy to be invited to any additional follow-up surveys?

( ) Yes I am happy to be invited / ( ) No I would not like to be invited back

64) Finally, we have one last question to determine if you have been paying attention. To show that you have read the information above, please ignore the statement below and select 'J rather than any of the vowels.

Please select all of the vowels below:

[ ] A / [ ] D / [ ] E / [ ] J / [ ] I / [ ] S / [ ] N / [ ] O / [ ] U

65) If you would like to receive an Amazon gift voucher for your participation in this survey please select which voucher you would like to receive.

( ) UK Amazon / ( ) US Amazon / ( ) None - I do not want an amazon gift voucher

66) If you would like to provide us with a different email address to receive your Amazon gift voucher, please provide us with one below:

Appendix B

Coding manual for the open-ended memory-related questions administered in Study 1 (Chapter 3)

STUDY ON MEMORY OF EU Referendum 2016

SURVEY 1-4: Memory for the results

OPEN-ENDED MANUAL
FOR

DATA ENTRY

This handbook contains the coding scheme for the following questions:

Questions:

1. What time was it when you found out the results?
2. How did you learn the outcome?
    a. Forced Choice option
    b. Comments
3. Where were you when you found out the results?
4. Who were you with?
5. What were you doing beforehand?
6. What did you do immediately after?

*References to the questions mentioned above will be cited throughout this coding document, therefore please use above information as a reference when coding.

Notes: Each question will be on a separate tab. In order to code some of the questions, you may need to relate back to a previous question.

Columns 1-4 of each tab will be exactly the same so that it is easy to identify participants.

Reference Columns

Column 1

Heading: “Time Code”

Coding: Assigned by experimenter to represent survey session number (e.g. A, B, C or D. Coders should be naïve to the actual session number.)

Column 2

Heading: “Response_ID”

Coding: Assigned to each participant by SurveyGizmo (e.g. 100, 256, 320).

Column 3

Heading: “Recruit_Type”

Coding: V = Volunteers / P = Prolific / P_UK = Prolific UK / P_US = Prolific US / RP = Research Panel / SONA = SONA

Column 4

Heading: “Unique_ID”

Coding: Assigned by experimenter based on following information: Survey Number; numerical pair, alphabetical pair then Recruit_Type (e.g. T125ABP)

Tab 1: What time was it when you found out the results?

Columns 1-4

These columns should be kept constant across each tab and should be set up already by the experimenter.

Columns 5-8

Heading: Question 1: “What time did you find out the results?”

Overview: The participant may recall time in various ways. For this reason, two columns (Columns 6-7) record different aspects of any time stated:

Column 5: This column is the exported data from the survey.

Column 6: registers time using the specific minute or average of the range stated.

Column 7: registers the time as precise or approximate.

Notes: You may refer to other questions to help code more accurately for this question. However, if a discrepancy exists between what is written in Q1 and other responses, then use the information provided in Question #1.

You must enter time in ***Military hours***; that is, 2:00 p.m. = 14:00.

For special military-time coding for "Not Stated" and "Not Applicable" see coding for column 6.

Column 5

Heading: Question 1: “What time did you find out the results?”

Notes: This column is the exported data from the survey.

Column 6

Heading: “Question 1 – Time Recalled (Specific or Average)”

Notes: If response is narrative and you can translate this into a time, then do so. If narrative is too vague to be translated, then code as “Not Applicable” or highlight and ask.

Actual time results were announced (for reference): morning of 24th June 2016

Coding: Enter as either the specific time OR the average of the time span stated (e.g. 9 - 10 = 9:30) '0:00 = Not Stated or Don't Know (No response was given).

First type apostrophe when entering data. If not, data will display 12:00:00, designating the incorrect entry of midnight.

'24:00 = Midnight (first type apostrophe when entering data). If not, data will

display "0:00" (Military hours) and thus code as "Not Stated".

'25:00 = Not Applicable (time stated vaguely, such as "after incident").

Again, first type apostrophe when entering data. If not, data will display "1:00" (military clock starts over again) and thus code as

"1:00 a.m."

Column 7

Heading: “Question 1 – Time Recalled (Precise or Approximate)”

Notes: "Approximate" = any phrase implying estimation: e.g. "about", "around".

Coding:

0 = Not stated (No response given in Q1 or Q2) or Don't Know.

1 = Stated as specific to the minute (e.g. 9:22)

2 = Stated as specific range of time (e.g. 9:10 – 9:20)

3 = Stated as approximate to the minute (e.g. "around" 10:05)

4 = Stated as approximate range of time (e.g. "around" 10:10 – 10:30)

5 = Stated not as time, but as "Morning" or as reference to BST (from 6:00 a.m. –11:00 a.m.)

6 = Stated not as time, but as "Mid-Day", or as reference to BST (from 11:00 a.m. – 1:00 p.m.)

7 = Stated not as time, but as "Afternoon", or as reference to BST (from 1:00 p.m. – 5:00 p.m.)

8 = Stated not as time, but as "Evening", or as reference to BST (from 5:00 p.m. – 7:00 p.m.)

9 = Stated not as time, but as "Night", or as reference to BST (from 7:00 p.m. – 12 midnight)

10 = Stated not as time, but as "Early hours", or as reference to BST (from 12:00 p.m. – 6:00am)

11 = Stated either as time or not, but which refers to "Next Day" (25/06/2016)

12 = Stated either as time or not, but which refers to "Later that Week"

13 = Stated either as time or not, but which refers to "After Week of 24/06/2016"

2) Tab 2: “How did you learn the outcome?”

Columns 1-4

These columns should be kept constant across each tab and should be set up already by the experimenter.

Columns 5 -7

Overview:

Column 5: This column is the exported data from the survey and was a forced choice option.

Column 6: This column is the exported data from the survey and is blank for most responses.

Column 7: This column is the exported data from the survey and an open text for the participant to enter additional information.

Column 5

Heading: "Question 2 – First Account (How did you learn the outcome?)"

**Not open ended. Selection of the following:*

You do not need to code anything for this column – it is just to assist with coding.

Options:

0 = Not stated

1 = TV

2 = Internet

3 = Internet Friends/Family

4 = Newspaper

5 = Radio

6 = Other

Column 6

Heading: "Question 2a – First Account (How did you learn the outcome?)" *Other*

Coding: No coding required.

Column 7

Heading: "Question 2b: "How did you learn the outcome?" *Comments*.

*There was the option to leave this question blank, therefore there may not be an answer from every participant. Please code the primary source. This column is the exported data from the survey.

Tab 3: Question 3:"Where were you when you found out the results?"

Columns 1-4

These columns should be kept constant across each tab and should be set up already by the experimenter.

Columns 5-8

Overview: The participant may recall either an Actual Site or Geographic Site or even a specific room location. For example, they may say "at home, in NYC. In this example, "home" would be the selection for "Actual Site", and "NYC" would be the selection for "Geographic Site". Additionally, column 8 codes for any specific room locations that are mentioned.

Column 5: This column is the exported data from the survey.

Column 6: This column is to code the *Actual Site.*

Column 7: This column is to code the *Geographic Site.*

Column 8: The coding the Specific *Room Location.*

Column 5

Heading: Question 3: "Where were you when you found out the results?"

Notes: This column is the exported data from the survey.

Column 6

Heading: "Question 3: Where were you when you found out the results?" (Where – Actual Site)"

Coding: Enter location of participant where first awareness of results took place.

For Actual Site column:

Dorm constitutes "Home"

Any public building [courthouse, railroad station] becomes "Place of Business"

Any place of business (e.g. dentist, govt. bldg., conference centre, gym (if outside school), hotels, etc.) becomes "Place of Business"

If the location of a building is identified as being within a school campus/area

(e.g. dining hall), then code for school. [An exception would be if in the dorm.

Then "Home" would take precedence.] Another example would be "elevator"

(if at work, code for "work office", but if at home, code for "home")

Coding:

0 = Not stated

1 = Home – Personal (include dorm room, home office)

2 = Home of someone else (include: family, friends)

3 = School (include: being on-campus, in classes, or when specified, engaged in school activity or school meetings)

4 = Work office (include: work outside of home and meetings either unspecified or related to personal employment)

5 = Traveling (train, car, bus, subway, walking)

6 = Airport &/or Airplane

7 = On the street/Outdoors

8 = On vacation (if stated or deducible)

9 = Place of Worship (church, temple, religious retreat)

10 = Place of Business (store, office not pertaining to personal work)

11 = Other

Column 7

Heading: "Question 3 – First Account (Where – Geographic Site)"

Notes: Participants may enter more specific locations relevant to the country/city they were in.

Coding: 0 = Not stated

1 = United Kingdom (England, Scotland, Wales, Ireland)

2 = Specific UK city

3 = United States

4 = Specific US State/City

5 = Foreign Country

6= Foreign City

Column 8

Heading: "Question 3 – Where were you when you found out the results?" (Where – Specific room location)"

Notes: Participants may enter more specific locations relevant to the room they were in.

Coding: 0 = Not stated

1 = Bed/ Bedroom

2 = Living room

3 = Kitchen

4 = Other room

Tab 4: Question 4 – "Who else was there when you found out the results?

Columns 1-4

These columns should be kept constant across each tab and should be set up already by the experimenter.

Columns 5-29

Overview:

This answer could include various parties, there will be multiple columns, with each party having its own column (e.g. “Question 4 - Who (Parent)”).

Whom the participant was with

0 = Not stated (no coding applicable to that party/column)

1 = Was with the person

Entries alluding to boyfriend/girlfriend, "partner", companion = "Spouse/Lover"

Unclear relationships or potential overlap of relationships = "Other"

Entries of occasional familiarity (e.g. doorman, friend's mom) = "Acquaintance"

Entries of consistent familiarity (e.g. teammates) = "Close Friend"

Entries implying unfamiliarity (e.g. repairmen, crew worker, etc.) = "Stranger"

Work-related relationships (e.g. office manager, client, etc.) = "Colleague"

Entries denoting "Can't remember", "Don't Know" = "Not Stated"

"None" will be coded as "Other"

Do not include pets in “Other”. If only “pets” are mentioned, then enter “Alone”.

Column 5

Heading: Question 4 – “Who else was there when you found out the results?

Notes: This column is the exported data from the survey.

Columns 6-29

Heading: “Question 4 – Who else was there when you found out the results?

(Who – Selection List of Other Parties)”

Coding: (See coding box on prior page)

Selection of Other Parties

6. Spouse/Lover

7. Parent

8. Child

9. Sibling

10. Parent In-law

11. Child In-law

12. Sibling in law

13. Other Blood Relative

14. Close Friend (when designated as such or suggestive of consistent familiarity")

15. Acquaintance Friend (when designated or suggestive of occasional familiarity)

16. Colleague

17. Roommate

18. Teacher

19. Student

20. Classmate

21. Neighbor

22. Fellow Commuter (if specified or deducible; if not, enter as “stranger”)(not passerby on street/sidewalk – someone riding on transit)

23. Stranger

24. Specific Media Figure/Person (only if name of individual is given)

25. Unidentified Media Figure/Person (stated as unspecified person, not as medium or program – i.e. announcer, news-anchor, DJ, reporter)

26. Media Program/Channel/Station (if specified): e.g. BBC, Sky News

27. Govt. Official (Police, Fire Dept., Govt worker, Security personnel)

28. Medical Personnel (Doctor, Nurse, EMT)

29. Alone (if stated as such – e.g. “no one there”, etc.)

Column 30

Heading: Question 4 – Who else was there when you found out the results?

(Who – Alone)”

Explicitly mentioned that they were alone

Coding:

0 = Not stated

1 = Stated (only if mentioned within context, not inferred)

Column 31

Heading: “Question 4 – Who else was there when you found out the results? (Who – Other)”

Coding: Enter “1” (for single or multiple entries)

0 = Not Stated

Tab 5: Question 5 – What were you doing beforehand? ”

Columns 1-4

These columns should be kept constant across each tab and should be set up already by the experimenter.

Columns 5-6

Notes: If more than one activity is mentioned, only code for the MAIN ACTIVITY stated THAT IMMEDIATELY PRECEDED AWARENESS.

Traveling (unspecified and not connected to a chore/errand, to transit, commuting or to walking to/from work/school) becomes "Traveling - General"

Category "Running Errands/Doing Chores" will NOT include "Traveling (unspecified)"

Walking as exercise (i.e. constitutional) becomes "Recreationally Engaged"

Break between classes or on break at work becomes "Leisure Activities"

Being in class, waiting for class to begin, for professor, or studying = "Working"

Having conversation in person constitutes "Communicating"

Any outside appointment not work-related constitutes "Running Errands…"

Entries denoting "Not sure", "Don't recall", etc. constitute "Not Stated"

Entries alluding to "prayer" or church-going constitute "Leisure Activities"

Entries alluding to dining other than breakfast constitute "Leisure Activities"

Column 5

Heading: "Question 5 – What were you doing beforehand?"

Notes: This column is the exported data from the survey.

Column 6

Heading: "Question 5 – What were you doing beforehand?"

Coding:

0 = Not stated

1 = Awaking (Sleeping, Waking up, Getting out of bed)

2 = Preparing for the day (Showering, Shaving, Dressing, Eating breakfast)

3 = Running errands/Doing Chores (Buying Groceries, Going to the Post Office, Walking or Feeding pets, Fixing up house or apt., Voting)

4 = Commuting (Train, Subway, Car, Airplane)

5 = Communicating (On Phone, On Internet, On Email, In person)

6 = Working (Office or Home)

7 = Recreationally engaged (Playing sports or games, Doing hobbies, Exercising)

8 = Leisure Activities (Resting or Napping, Looking out the window, Pleasure reading, Reading newspaper, Watching TV (not news), Listening to music on radio/stereo, Surfing the Internet (not news))

9 = Live Information Gathering (News on TV/radio/Internet)

10 = Traveling – General

11 = Other

Tab 6: Question 6 – What did you do immediately after? "

Columns 1-4

These columns should be kept constant across each tab and should be set up already by the experimenter.

Columns 5-8

Overview: The next three columns (Columns 61-63) will record primary, secondary, and additional recall; however, these columns will focus on behavioral responses that account for what the PARTICIPANT was doing following awareness of the event.

NOTE: List behaviors in their CHRONOLOGICAL ORDER (which may not necessarily be the order stated in the narrative). For example, the participant stated: "After hearing the news of the referendum results, I got out of bed, called my spouse to tell him and then got ready for work." The chronological order is as follows: First, the participant got out of bed; Second, they called their spouse, Third, they got ready for work. Hence, the entry for Primary behavior would be "9" for "Got out of bed" and the secondary behavior would be "5" for "Communicated" and the additional behavior would be '9'.

Note: Only enter one response for primary and secondary columns.

Column 5

Heading: Question 6 – "What did you do immediately after finding out the results?" (Behavioral Response)
Coding: This column is the exported data from the survey.

Column 6

Heading: "Question 6 – "What did you do immediately after finding out the results?" (Behavioral Response – Primary)"

Coding: Only enter 1st behavior stated (chronologically)

See coding box on following page:

Column 7

Heading: "Question 6 – "What did you do immediately after finding out the results?" (Behavioral Response – Secondary)"

Coding: ONLY ENTER 2nd BEHAVIOR STATED (chronologically)

See coding box on following page:

Notes: Entries related to going to church, praying constitute "Sought Help"

Entries related to going home or in transit (unspecified) remains as "Other"

Entries stated as "Nothing" constitute "Other"

Entries stated as "Don't remember" constitute "Not Stated"

0 = Not applicable

1 = Emoted (Include: Cried, Yelled, Screamed, Shouted)

2 = Physically responded (Include: Collapsed, Sat, Jumped, Stood, Paced, Ran)

3 = Followed news (Include: TV, Radio, Internet, Videotaped the news)

4 = Went to eyewitness (Include: from window, from street)

5 = Communicated (Phone call, E-mail, "IM", Talked, Verbally responded)

6 = Joined other people / going to speak to/wake up others

7 = Took photographs/Video/Went to get camera

8 = Wrote (e.g. diary/journal entry)

9= Preparing for the day

10 = Breakfast – having tea/coffee making breakfast/ tea/coffee/ drink

11 = Sought help (e.g. prayed)

12 = Resumed *prior* activity (i.e. if different from that in which the person was engaged when awareness of the results occurred) See note below

13 = Other

14 = Going to work/school

NOTE: "Resumed *prior* activity" means returning or reverting back to the activity engaged in prior to awareness of the event.

Hence, this selection is determined by noting the moment of awareness of the event and coding for the activity in which the participant chose to engage in immediately thereafter. This does not mean that if the participant was watching the news and learned of the results on TV that continuing to watch the news means he/she resumed the prior activity. The entry for that would be "3" for "Followed news", because that is what the participant chose to do upon awareness of the event. Nor does it mean that if the participant was on the phone with someone who informed him/her of the event, that continuing to talk on the phone means the participant resumed the prior activity. The entry for that would be "5" for "Communicated".

Column 8

Heading: "Question 6 – "What did you do immediately after finding out the results?" (Behavioral Response - Additional)

Notes: Entries related to going to church, praying constitute "Sought Help"

Entries related to going home or in transit (unspecified) remains as "Other"

Entries stated as "Nothing" constitute "Other"

Entries stated as "Don't remember" constitute "Not Stated"

Column 9-21

Question 6 - # and type of incidents recalled

Overview:

These columns (Columns) are meant to record distinct units of narrative by category type and frequency with which the overall category is included. Since subjectivity exists as to what constitutes the grouping of recalled moments into a single incident, isolated incidents are combined into general categories, each with their own columns (see coding below).

Notes: Only record DISTINCT entries between AND within the categories:

Units of the same information that are repeated within the narrative should not be recorded as separate entries. For example, the participant wrote, "I woke up and got dressed. After getting dressed, I then shaved…" In this case, do not treat the repetition of "getting dressed" as two entries. In other words, since "getting dressed" is repeated, it would be counted only once. Since "shaving" and "getting dressed" are distinct entries within the category "Preparing for the Day", the # of total entries coded for that category column would be "2", not "3".

Recording "0" and "Other":

If a particular coding category does not apply to the response, then enter "0" in the column for that category. If the response in Question #6 does not lend itself to any of the coding selections, then enter a "0" in all columns, except for "Other", where you enter "1".

"Not Stated" -- Additional Note for # & Type of Incidents Recalled:

The category column "Not Stated" is not included in this particular section of Question #6. In the case of there being no response at all for Question #6, simply enter "0" for all columns in this section. As well, the issue of "Not Stated" already will have been reflected by the coding in Column 6 "Question #6 – Not Stated".

More Notes: Traveling (unspecified and not connected to a chore/errand) becomes "Traveling"

Category "Running Errands/Doing Chores" will NOT be coded for "Traveling"

Walking as exercise (i.e. constitutional) becomes "Recreationally Engaged"

Break between classes or on break at work becomes "Leisure Activities"

Being in class, Waiting for class to begin, for professor, or Studying = "Working"

Any outside appointment not work-related constitutes "Running Errands…"

Entries denoting "Not sure", "Don't recall", etc. constitute "Not Stated"

Entries alluding to "prayer" or church-going constitute "Leisure Activities"

Entries alluding to dining other than breakfast constitute "Leisure Activities"

Awaking (Sleeping, Waking up, Getting out of bed)

Preparing for the day (Showering, Shaving, Dressing, Eating Breakfast)

Running errands/Doing Chores (Buying Groceries, Going to Post Office,

Walking or Feeding pets, Fixing up house/apt., Voting)

Travelling (Train, Subway, Car, Airplane, Walking to work or appointment)

Communicating (On Phone, On Internet, On Email, In person)

Working (Office, Home, School, Classes, Meetings)

Recreational Activities (Playing sports or games, Doing Hobbies, Exercising,

Constitutional (Walking – if alluded to as recreational)

Leisure Activities (Resting or Napping, Looking out the window,

Reading paper, Watching TV (not news), Listening to radio/stereo (either music or unspecified), Surfing the Internet (not news or unspecified))

Live Information Gathering (News on TV, Radio, Internet, Taped the news)

Hearing (Overhearing conversation)

Eye-witnessing (Street activity, political activity, Picture-taking)

Helping (Assisting)

Other (Enter "1")

Columns 9-21

Heading: "Question 6 – "What did you do immediately after finding out the results?" (# & Type of Incidents Recalled)"

Coding: Within each column, record the # of times any incidents are mentioned.

Column 22

Heading: "Question 6 – "What did you do immediately after finding out the results?" (# & Type of Incidents Recalled – Other)"

Coding: Enter "1" if applicable

0 = Not applicable

Appendix C

Demographic Information

1. How old are you? _____ Date of birth? ___________ Gender: F M
2. How many years of education have you received, including grade school?
   _________________________ (12 = High school diploma, 16 = Bachelor's degree)
3. Please indicate your ethnic origin:

☐ White – British	☐ Black or Black British –African
☐ Other White	☐ Black or Black British – Caribbean
☐ Asian or Asian British – Bangladeshi	☐ Other Black background
☐ Asian or Asian British -- Indian	☐ Mixed – White and Asian
☐ Asian or Asian British -- Pakistani	☐ Mixed – White and Black African
☐ Asian or Asian British -- Chinese	☐ Mixed – White and Black Caribbean
☐ Other Asian background	☐ Other Mixed background
☐ Other Ethnic background: _____________	
☐ Not known	☐ Information refused

4. What is your profession? If retired, please state your former profession:______________________
5. How many hours did you sleep last night? ___________
6. How many hours do you usually sleep each night? ________
7. How would you describe your overall health, on a scale from 1 to 9
   (1 = very poor health, 9 = excellent health)? __________
8. What do you feel your stress level is today on a scale from 1 to 9
   (1 = very low, 5 = moderate, 9 = very high)? ___________
9. How does your stress level today compare with your usual stress level?
   (1 = much lower, 5 = same as usual, 9 = much higher)? ___________
10. Is English your first language? _________ If no, what age did you learn it? _________
11. What is your handedness?
    ☐ Right ☐ Left ☐ Both
12. Pre-menopause women only: How many days ago was the first day of bleeding of your last menstrual cycle? _______ (Please ask for a calendar if you need to consult one.)
13. Menopause and Post-menopause women only: Have you ever taken an estrogen replacement medication?
    Yes No

a. If you answered "Yes" above, do you currently take this medication?

Yes No

i. If "Yes", for how long have you been taking this medication? __________

ii. If "No", how long ago did you stop taking this medication? ____________. For how long did you take this medication before you stopped taking it? ___________

14. Please list any medications/drugs you are currently taking and the dosage (amount and frequency)—including over-the-counter drug, alternative remedy and prescription medication.

A. Hormone replacement – estrogen, estrogen/progestin combination
name ________________ dosage ________________

B. Antidepressant or anti anxiety medication
name ________________ dosage ________________

C. High Blood Pressure medication
name ________________ dosage ________________

D. Thyroid medication
name ________________ dosage ________________

E. Heart disease related
name ________________ dosage ________________

F. Pain relievers
name ________________ dosage ________________

G. Sleep Aides
name ________________ dosage ________________

H. Inhaler
name ________________ dosage ________________

I. Headache relievers
name ________________ dosage ________________

J. Other Medications/Over the Counter Drugs and Alternative Remedies
name ________________ dosage ________________

name ________________ dosage ________________

name ________________ dosage ________________

name ________________ dosage ________________

12. Are you CURRENTLY under a doctor's care for:

__ Heart disease (including coronary artery disease, angina, and arrhythmia)

__ Vascular disease

__ Diabetes

Appendix D

Cognitive assessment battery administered at the end of Study 2 and 3 (Chapters 4 and 5)

Retesting

The Cognitive Ageing Battery was administered to participants on the second session. The test included assessments of working memory span, verbal fluency, executive function, episodic memory.

Wechsler Block design. The block design task comprises of nine wooden cubes, that each have two white, two red and two half-red and half-white painted sides and nine patterned shapes. Participants are initially given four blocks and are asked to replicate the first six patterned shapes one at a time using the blocks. For the first five trials, participants are given one minute to complete the pattern correctly and are scored based on the length of time it takes them to successfully replicate the pattern. After the fifth trial, participants are then given all nine blocks and are asked to replicate a further four patterns but are given two minutes to complete the task. The maximum score is 51.

The Consortium to Establish a Registry for Alzheimer's Disease (CERAD I & II; Morris, Heyman, Mohs, Hughes, van Belle, Fillenbaum et al., 1989). The CERAD consists of two parts; immediate and delayed recall and recognition. In the first task, the experimenter reads out loud a list of 10 words (the words are in a different in each list). After each time the list is read out loud, the participant is asked to recall as many of the words that they can remember from the list. For each one they receive a score out of 10.

The second part of the task is the delayed recall and recognition and is administered after the Stroop task. For the free recall test, participants are asked to recall as many of the 10 words that were included in the original three lists in any order. They are scored out of 10. Finally for the recognition test, the experimenter reads out a list of 20 words including the 10 original words and 10 new words. The participant is asked to determine whether the item was included or not and are given a score out of 20.

Trail making test (TMT; Army Individual Test Battery, 1944). This test is split into two parts and measures visual attention and task switching. The first part consists of a piece of paper with 25 individually numbered circles that are randomly positioned. Participants must draw a line connecting the numbered circles in a consecutive order, starting from '1' and finishing at '25' without lifting the pen from the paper and as quickly as possible. The second task is similar to the first except this time, the 26 circles are either numbered (1-13) or alphabetized (A-L). Again, the participant is required to draw a line connecting the circles in a consecutive order but this time must alternate between numbers and letters (e.g. 1, A, 2, B, 3, C, etc.). For both tasks, the participant is timed.

Stroop Task. The Stroop task measures an individual's ability to inhibit cognitive interference. Participants are presented with one of four words on the computer screen, 'green', 'blue', 'red' and 'purple' that are printed in one of the four colors. The participant is required to indicate the color of the ink, rather than the word, by pressing the corresponding colored keys. Half of the trials are congruent i.e. the ink color matches the word and half of the trials are incongruent i.e. the ink color does not match the word. The interference score is calculated by subtracting the average incongruent accuracy from the average of the congruent accuracy score.

Verbal Fluency. Participants took part in a letter fluency task (words beginning with the letter 'F') followed by a category fluency task (animals) in which they were given one minute to say as many words associated with the letter "F" or the category of 'animals'. Each response was recorded by the experimenter. Derivatives of words and repeated words were not accepted as an answer.

Nottingham Extended Activities of Daily Living Scale. This scale assesses the types of activities that an individual does in their daily lives and whether or not they can complete certain activities by themselves or not. If they are able to complete the task on their own with little or no difficulty then they are given a '1', whereas if they are unable to do the task at all or require help, they are given a '0' thus a higher score represents a greater ability to carry out daily activities.

Mood assessment. A series of 14 questions relating to how the participant had been feeling in the last few days were administered. The items included statements like "I feel tense or 'wound up'" and "worrying thoughts go through my mind" with each question having four choices to choose from. Each four item scale differed depending on the question.

Screening

If participants had never completed the cognitive assessment before, then they were asked to complete the 'screening' version which includes all of the above tests with the addition of the following:

Vocabulary. This test includes a list of 32 words. Participants are asked to provide a brief definition such as one you would find in a dictionary. Participants are scored based on whether their responses meet certain criteria in

The National Adult Reading Test (NART). This test includes a list of 50 words that have atypical phonemic pronunciation. Participants are asked to read out loud each word and are scored based on the accuracy of their pronunciation.

Number copying. This task includes two sheets of paper upon which there are 10 rows of numbers printed on either side with space beneath for the participant to copy the numbers above. Participants are given two minutes to copy as many numbers as possible (Salthouse, Fristoe, & Rhee, 1996).

Appendix E

Item	Question	Scale / options
1	In general, how positive/negative do you currently feel?	*1 (very negative) - 7 (very positive)*
2	Please read each item and select the number corresponding to how intensely you feel that emotion at the moment. *Happy, pride, sad, anxious, frustrated, bored, calm, curious, joy, embarrassment, shame, contentment, amusement, anger, disgust, excitement, accomplishment, guilt, interest, fear, irritation*	*1 (not at all) - 7 (extremely)*
3	How strongly are you currently stressed?	*1 (not at all) - 7 (extremely)*
4	Please read each item and answer the questions with “How true is this of you?” Select the appropriate number on the scale.	*1 (very true) - 7 (very untrue)* *1. Most of my life lies ahead of me.* *2. There is plenty of time left in my life to make new plans.* *3. I feel like time left in my life is limited.* *4. Many opportunities await me in the future.* *5. I expect that I will set many new goals in the future.* *6. My future is filled with possibilities.* *7. My future seems infinite to me.* *8. I could do anything I want in the future.* *9. I have the sense time is running out.* *10. There are only limited possibilities in my future.* *11. As I get older, I begin to experience time as limited.*
5	Next, we would like you to answer what you were doing before you heard the signal and started the survey. What were you doing before you heard the signal? SELECT ALL that apply to you.	*Intimate relations, Socialising, Relaxing, Pray/Meditating, Eating/Drinking, Exercising, TV/reading, Shopping, Cooking/Housework, Napping, Working/Studying, On a computer, On the phone, Walking, Driving, Other*

6	How important is the task that you were doing before this signal?	*1 (not at all) - 7 (extremely)*
7	Did you have any problems with the task you were doing?	*1 (not at all) - 7 (extremely)*
8	Did your mind wonder during the task you were doing?	*1 (not at all) - 7 (extremely)*
9	If so, what were you thinking about during your mind wandering?	*Nothing/ something pleasant / something unpleasant / something neutral / I don't remember*
10	What I was doing before the survey was something that I did by my own choice.	*1 (not at all) - 7 (extremely)*
11	I feel I have choices.	*1 (not at all) - 7 (extremely)*
12	Next we have a few questions about persons you were with. Who were you with before you started this survey? Select ALL that apply.	*Alone, Spouse ,Parents, Children, Siblings, Other family, Romantic partner, Friend, Neighbour, Coworker, Service provider, Professors, Teachers, Lecturers, Boss, Others*
13	How close is this person/are these people to you?	*1 (not at all) - 7 (extremely)*
14	How important is this person/are they to you?	*1 (not at all) - 7 (extremely)*
15	How warm is the other person/are they?	*1 (very warm) - 7 (very cold).*
16	How supportive is this other person/are they?	*1 (very supportive) - 7 (very cold).*
	Next, we would like you to answer a few questions about what you were doing before you heard the signal.	
17	Where were you?	*Home, Office/at work, University, Garden at home, Outdoor (not home), Indoor (not home)*
18	Did you drink any of the following beverages in the last 30 min? Select ALL that apply to you.	*Coffee / Tea / Energy drink / Alcohol*
19	Have you smoked in the last 30 min?	*Yes / No*
20	Did you engage in any exercise in the last 30 min?	*Yes / No*
21	If so, how intensive was the exercise?	*1 (not at all) - 7 (extremely)*

22	How do you feel about your overall health?	*1 (very bad) - 7 (very good)*
23	How do you expect you will feel when you complete this survey next time?	*1 (very negative) - 7 (very positive)*
24	What were you doing when answering the survey this time? SELECT ALL that apply.	*Socializing, Relaxing, Pray/Meditate, Eat/Drink, TV/reading, Cooking/Housework, On a computer, On the phone, Walking, Other*
25	Did you do any of the following when answering the questions? SELECT ALL that apply.	*Sitting, Standing, Lying down, Talking, Walking, Running, Writing, Texting, Coughing/Sneezing, Yawning, Bending, Stretching, Changing posture, Laughing*
26	How much distracted were you when answering the questions?	*1 (not at all) - 7 (extremely)*
27	Did you move any parts of your body when answering the questions?	*1 (not at all) - 7 (extremely)*