

**EXTRINSIC AND INTRINSIC FACTORS INFLUENCING THE POSITIVE MEMORY  
BIAS IN AGING**

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### Abstract

Emotional experiences are more likely to be remembered than more neutral, mundane ones. In young adults, negative information may be particularly memorable. Yet, an interesting change seems to happen in aging: As adults grow older, they may start remembering positive information more often than negative information. This positive memory bias in aging is commonly observed and is often explained in terms of changing time perspectives and motivation across the lifespan (i.e., Socioemotional Selectivity Theory; Carstensen, Isaacowitz, & Charles, 1999). However, few studies have considered the basic interactions between memory and emotion that could influence this positivity bias. In this thesis, I examine whether certain factors partially independent of aging (i.e., *semantic relatedness* and *distinctiveness*, Study 1; *mood*, Studies 2-4), might influence the presence and magnitude of the positivity bias in memory. In Study 1, I explore the cognitive mechanisms required to produce the positivity bias and apply what is learned in this paper to investigate, in Studies 2-4, whether differences in mood could explain why the positivity bias occurs. In all studies, memory is measured using immediate free recall of positive, negative, and neutral pictures. In Study 1, I manipulate item interrelatedness (i.e., the extent of relatedness among pictures of a same category) and relative distinctiveness (i.e., the processing of a picture category at the same time as or in isolation from the others) to show that older adults' emotional memory can be entirely explained by these two factors. The distinctive processing of positive pictures relative to other pictures is necessary for producing a positivity bias in older adults, which completely disappears when the distinctive processing of positive pictures is removed. Therefore, in subsequent studies I encourage the distinctive processing of items to increase the likelihood of observing a positivity bias and its possible interaction with mood. In Study 2, I test whether differences in mood predict differences

in emotional memory bias in young and older adults using a video mood induction technique validated in a separate pilot study. In Studies 3 and 4, I further test the effect of mood on the positivity bias beyond any age-specific factors, by examining young adults only. This serves to reduce the likelihood of confounds that might exist between age groups (i.e., related to neurocognitive changes or decline), in order to study the true effects of mood on the positivity bias. In Study 3, I use a written priming task to experimentally manipulate mood and time perspective in young adults. In Study 4, I compare differences in naturally occurring moods and emotional memory in two separate young adult samples: university students and non-students. The experimental mood manipulations have minimal influence on the presence of a negativity bias in young adults (Studies 2 and 3), and influence to a small extent the memory advantage of positive over neutral material in older adults (Study 2). Non-student young adults show a similar preferential memory for positive material that is different from what is observed in university students, but this is not easily attributed to differences in mood (Study 4). In light of these results, I argue that the positivity effect in aging memory reflects a temporary contextual advantage for positive information that is not permanent or irreversible. Rather, it seems to depend in varying degrees on the context of study (i.e., relatedness and distinctiveness), mood, and the young-adult reference group. This has implications for how future research defines and studies the positivity effect in aging.

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### **Contribution of Author**

Kylee Ack Baraly conceived, designed, and created the experiments in this dissertation, with guidance and input from Dr. Patrick Davidson and Dr. Pascal Hot. Kylee Ack Baraly selected and validated the picture stimuli, programmed the tasks on E-Prime and Qualtrics, recruited and conducted testing for the pilots and main experiments, scored and verified memory and questionnaire data, screened and verified all physiology data, and conducted all statistical analyses and interpretation of results. Students of Dr. Davidson and Dr. Hot's laboratories helped with selecting and editing video stimuli, programming a pilot study on Qualtrics, recruiting and testing participants, scoring memory and questionnaire data, screening physiology data, and reviewing the first manuscript for submission. The results of the first study have been published in the journal *Memory and Cognition*, and the rest are being prepared for submission to other journals.

**CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW**

With our aging population and increased awareness of dementia, many people associate aging to declining memory and fear it will affect them later in life. But in aging, not all aspects of memory are impaired and in fact, not all memory changes are negative. Some might even be positive and reflective of a healthy aging process. For example, in a classic *paradox of aging*, emotional memory seems to change positively over time: When adults are younger (typically those under 30), they will often remember negative information more often than neutral or positive information (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Yet, this is rarely the case in adults over 60 (Carstensen & DeLiema, 2018). Older adults seem to remember positive information more often than other types of information (i.e., negative or neutral). This memory advantage for positive information in older adults relative to young adults is commonly observed and is frequently referred to as the positivity effect in aging memory. How and why there might be a positivity effect in aging memory remains controversial.

My thesis addresses this issue in two parts. First, by identifying the cognitive processes that are necessary to produce a positivity bias in older adults (Study 1). Then, by investigating whether changes in mood can explain why there is sometimes a memory advantage for positive rather than negative information (Studies 2-4). This work seeks to clarify how and why there seems to be a positive memory bias in older adults to further our understanding of the normal memory aging process.

### **Positivity Effect in Aging**

#### **Definitions**

A fundamental inconsistency in the literature is the operational definition of the positivity effect. This has implications for the interpretation of results and needs to be considered at the

outset. Previously, the positivity effect has referred to any processing advantage in favour of positive information that is greater in older than in young adults (Carstensen & Mikels, 2005; Mather & Carstensen, 2005; Reed, Chan, & Mikels, 2014). This included findings in which, relative to young adults, older adults showed: a) enhanced memory for positive relative to neutral items (Yang & Ornstein, 2011); b) enhanced memory for positive relative to negative items (Fernandes, Ross, Wiegand, & Schryer, 2008; Fung, Isaacowitz, Lu, & Li, 2010); or c) decreased memory for negative relative to neutral or positive items (Chung, 2010; Langeslag & van Strien, 2009). But a *positivity preference* or *positive emotion-enhanced memory* in older adults (i.e., an advantage for positive over neutral material) does not preclude a *negativity preference* or *negative emotion-enhanced memory* (i.e., an advantage for negative over neutral material; Murphy & Isaacowitz, 2008). In fact, both a positivity preference and negativity preference are likely to occur because of emotion's generally greater relevance over neutral information (Ack Baraly, Hot, Davidson, & Talmi, 2017). Therefore, it is more useful to consider the emotional memory bias of positive information relative to negative information (see Table 1 for a summary of the terminology). A *positivity bias* occurs when positive information is remembered more often than negative information, and in contrast, a *negativity bias* occurs when negative information is remembered more often than positive information (Murphy & Isaacowitz, 2008; Reed et al., 2014). Therefore, the *positivity effect* can be operationalized as a positivity bias (positive information > negative information) that is greater in older adults relative to young adults. In other words, this would mean that there is also a *negativity effect* in young adults (i.e., larger negativity bias in young than older adults). These definitions are consistent with the ones used in a meta-analysis of 100 studies on the aging positivity effect in memory and attention (Reed et al., 2014).

Table 1

*Definitions of Emotional Memory Effects*

<b>Terminology</b>	<b>Relative rate of recall between types of stimuli</b>
Positivity preference (or positive EEM)	Positive > neutral
Positivity bias	Positive > negative
Positivity effect	Positivity bias in older adults > positivity bias in young adults
Negativity preference (or negative EEM)	Negative > neutral
Negativity bias	Negative > positive
Negativity effect	Negativity bias in young adults > negativity bias in older adults

*Note.* EEM = emotion-enhanced memory

The strongest evidence for age-group differences therefore lies in observing a positivity effect which accounts for relative differences in emotional memory bias. However, other age-group differences in positive memory could be measured by comparing the positivity preference between young and older adults or by directly comparing their recall of positive stimuli, yet this would not take into account age differences in memory ability. Clearly, there are many different ways to quantify emotional memory changes that might occur in aging. Throughout this thesis, I adopt the definition applied by Reed et al. (2014) and defined here as an age-group difference in positivity bias that is greater in older adults compared to young adults. This requires the highest standard of evidence, in comparison to “softer” definitions of the positivity effect. It is important to keep these distinct definitions in mind because they could influence the interpretation of findings and conclusions.

## **Main Findings**

Many studies show evidence of a shift in emotional memory biases with age, whereby older adults prioritize the processing and retention of positive over negative information. In eye-tracking studies, older adults spend more time looking at positive stimuli and less time looking at negative stimuli (Isaacowitz, Allard, Murphy, & Schlangel, 2009; Isaacowitz, Wadlinger, Goren, & Wilson, 2006a, 2006b). Consequently, they take longer to detect a target when it is preceded by a negative rather than positive image, an attentional bias not observed in young adults (Mather & Carstensen, 2003). This behavioural effect is accompanied by a greater involvement of the amygdala during the processing of positive compared to negative information in older adults, in comparison to young adults (Mather et al., 2004).

The positivity bias seems particularly strong in memory. Early work (Charles, Mather, & Carstensen, 2003) revealed a gradual shift from a joint negativity and positivity preference in young adults, to a moderate positivity bias (positive > negative) in middle-aged adults, to a larger positivity bias in older adults. Within a decade, there were close to 70 empirical studies of the positivity effect in memory (Reed et al., 2014). In their meta-analysis, Reed et al. (2014) revealed that older adults reliably demonstrated superior memory for positive over negative material. This finding was not limited to episodic memory, but was also observed in studies of autobiographical and working memory too.

Importantly, Reed et al. (2014) found that the positivity effect was more likely to appear in older adults when information processing was not constrained in a study, leaving them to process the information as they would naturally. For instance, the positivity effect was weaker in studies that explicitly instructed participants to memorize or judge stimuli during encoding. In contrast, the effect was stronger when they were simply told to watch the stimuli as they would a

television (Reed et al., 2014). In the latter case, there are no experimental constraints imposed on cognitive processing during encoding, allowing for the most natural processing of stimuli. This would likely maximize the expression of any naturally occurring differences in how young and older adults process and memorize emotional information.

In their meta-analysis, Reed et al. (2014) did not further consider differences in how memory is tested, but the positivity effect might also appear stronger when recall is unconstrained too. For instance, the positivity effect seems stronger in studies employing free recall rather than recognition memory tests (Charles et al., 2003; Tomaszczyk, Fernandes, & Macleod, 2008). Free recall might allow for more natural processing differences to be observed than in tests of recognition memory that use restricted forced-choice response options. Free recall typically requires more effortful retrieval than recognition, which could further strengthen the emotional memory pattern (Kensinger & Ford, 2020).

Reports of a positivity bias in older adults is surprising given the large body of work that has shown a strong negativity bias in young adults (Baumeister et al., 2001). From an early age, infants and children can detect threatening stimuli faster than non-threatening stimuli and can even remember them better too (LoBue, 2009; Vaish, Grossmann, & Woodward, 2008). Young adults (typically university students) pay more attention to and remember negative stimuli more often than positive stimuli (Baumeister et al., 2001; Reed et al., 2014). There are certain evolutionary advantages to this (Vaish et al., 2008), because attending to and learning from a negative stimulus (e.g., a wolf in a forest) is more important than a positive stimulus (e.g., a puppy in a park). It would seem that the “negativity bias in humans is so reliable that it can be considered a fundamental principle of human behavior” (Carstensen & DeLiema, 2018, p. 1). If the negativity bias is fundamental to human cognition and behaviour, why would this change

with age? A number of theories explore different reasons why positive information might become more valuable and prioritized in older adulthood. The leading explanation is based on age-related changes in social goals and motivation (Socioemotional Selectivity Theory; Carstensen, Isaacowitz, & Charles, 1999).

### **Theoretical Explanations**

The positivity effect was first derived from experiments on Socioemotional Selectivity Theory (SST), which began as studies on social judgments and goals (Carstensen et al., 1999), and quickly expanded to the realm of attention and memory (Carstensen & Mikels, 2005; Mather & Carstensen, 2005). It is only natural then, that SST is the most well supported theory in the literature. According to SST, people's perception of time and life expectancy change with age, leading to changes in their motivations and goals. Young adults perceive time as vast, not limiting them to the present but allowing them to focus on expanding their horizons for the future. As such, they are more likely to prioritize acquiring new information and increasing their social networks in order for them to address any unknown challenges in the future. Negative information is arguably more valuable than positive information (Baumeister et al., 2001), so young adults should prioritize negative information. In contrast, when time is perceived as limited—as is often the case for older adults—more resources are dedicated to satisfying present-oriented goals such as emotional satisfaction and meaningfulness (Carstensen & DeLiema, 2018; Mather & Carstensen, 2005). Older adults will therefore focus more on improving their own emotional well-being and strengthening existing relationships in order to capitalize on the time they have left in life. As such, older adults are more likely to focus on what is positive and avoid what is negative in an attempt to maximize their emotional well-being, leading them to allocate more attention and memory resources to positive events. Consequently, positive information

should become increasingly prioritized with age as older adults focus more on present-oriented goals because of their more limited view of time.

To my knowledge, there is only one study that has directly manipulated time perspective to measure its effects on emotional memory (Barber, Opitz, Martins, Sakaki, & Mather, 2016). Indeed, many studies are congruent with SST (for a meta-analysis, see Reed et al., 2014). However, many researchers interpret their findings within the framework of SST without directly measuring or manipulating time horizons. This is an important consideration because time horizon is linearly related to chronological age and should be account for separately in any research design. Alternative theories based on changes in cognition (Labouvie-Vief, 2003), emotion regulation (Charles & Luong, 2013), and neural function (Cacioppo, Berntson, Bechara, Tranel, & Hawkey, 2011; Dolcos, Rice, & Cabeza, 2002; Kensinger & Schacter, 2008; St. Jacques, Bessette-Symons, & Cabeza, 2009) in aging have been proposed but these cannot fully explain findings on the positivity effect, and SST continues to remain the most well supported explanation (for a review, see Carstensen & DeLiema, 2018).

### **Limitations in the Literature**

Although there has been a flurry of experiments on the positivity effect in memory within the past 15 years (Reed et al., 2014), this is still a relatively new field and there are many research gaps to address. Disagreements remain over the veracity and cause of the positivity effect (Kan, Garrison, Drummey, Emmert Jr., & Rogers, 2017), because of a general lack of empirical evidence (Grühn, Sharifian, & Chu, 2016). Studies exerting maximum experimental control are needed to understand the mechanisms underlying the positivity effect and why it occurs, while also accounting for common confounds in aging research.

Few studies have considered the basic interactions between memory and emotion that could influence the positivity bias. For instance, SST describes changes in social goals and motivations, and alternative theories focus on cognitive capacity or neural degradation. Yet, the positivity effect is a change in the emotional memory bias across the adult lifespan. *However, little to no work has considered the fundamental interactions between emotion and memory when examining the positivity effect.* There may be several cognitive factors supporting emotional memory that are partially independent of aging, which could influence the presence and magnitude of the positivity bias. In my thesis, I examine relevant aspects of emotion-enhanced memory and mood-congruent memory, two areas at the intersection of emotion and memory research. I use extrinsic factors (item interrelatedness and distinctiveness) from the emotion-enhanced memory literature to explain *how* the positivity bias occurs, in terms of the required underlying cognitive processes. These extrinsic factors are important for explaining emotional memory in young adults and likely affect emotional memory, and specifically the positivity bias, in older adults too. Then, I consider whether an intrinsic factor—mood—can explain *why* a positivity bias might frequently occur in older adults but not in young adults. These age groups tend to differ in their mood at the start of experiments, and because of mood's influence on memory, this could also contribute to age differences in emotional memory biases. Together, this work helps explain how and why a positive memory bias seems to occur with age.

### **Emotion-Enhanced Memory (Extrinsic Factors)**

Remembering past events is important so we can respond appropriately to similar occurrences in the present and future (Gershman & Daw, 2017). However, it is not possible to remember all of our past events, therefore we must determine which are more likely to be useful. Emotion serves as a useful indicator of the potential value of a stimulus and could indicate that

priority should be given to remembering that particular stimulus or event (for a review, see Ack Baraly et al., 2017). Researchers have known for a long time that emotion improves memory (James, 1890; Yerkes & Dodson, 1908) and many studies show emotion-enhanced memory (EEM) in humans and animals alike (McGaugh, 2004). For instance, people are generally able to remember an emotional story or set of pictures better than more neutral stories and pictures (for reviews, see Hamann, 2001; Kensinger & Schacter, 2016; LaBar & Cabeza, 2006; Phelps, 2004; Talmi, 2013), and this emotional memory advantage may grow stronger over time (Yonelinas & Ritchey, 2015). The EEM effect can include both negativity and positivity preferences, as both types of emotional material are recalled more often than neutral material<sup>1</sup>. This could result from emotion influencing the encoding, consolidation, and/or retrieval of memories.

### **Arousal-Modulated Consolidation**

For many decades, most research focused on emotion's effects on consolidation to explain EEM. The predominant theory of EEM, the modulation model (Cahill & McGaugh, 1995; McGaugh, 2000, 2015), has mapped out the physiological and neural influences of emotional arousal on long-term memory. According to the modulation model, EEM results from increased levels of physiological arousal during an emotional event that enhance consolidation over time through amygdala-hippocampal interactions. More specifically, when an emotional event occurs, there is an increased release of adrenal stress hormones that increase activity in the amygdala (McGaugh, 2004). The amygdala then increases the likelihood of consolidating the emotional memories by strengthening the activated synapses in the hippocampus (synaptic tagging and capture; Frey & Morris, 1998; Richter-Levin & Akirav, 2003). This ensures that early long-term potentiation (LTP) at the synapses persists into late LTP, leading to long-lasting

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<sup>1</sup> As defined in Table 1 (i.e., negative > neutral; positive > neutral).

memories. But the process of synaptic tagging and capture, including de novo protein synthesis, can last up to several hours (Kandel, Dudai, & Mayford, 2014). Indeed, studies supporting the modulation model include study-test delays of at least one hour, and commonly 24 hours or more.

However, EEM also appears when participants are tested shortly after encoding. The immediate memory-enhancing effects of emotion (i.e., immediate EEM) cannot be explained by modulated consolidation because late LTP would not yet be complete. Therefore, immediate EEM is more likely mediated by encoding and retrieval processes that are linked to the fast consolidation (i.e., early LTP) of memories. Indeed, most positivity effect studies using free recall include study-test delays of one hour or less (e.g., Charles et al., 2003), likely to avoid possible floor effects. In these studies, modulated-consolidation could not fully account for the positivity effect because late LTP would not yet be complete (Kandel et al., 2014). This would suggest that for the most part, studies on the positivity effect in which brief study-test delays are used, are likely assessing early LTP and factors that influence encoding and retrieval processes.

### **Cognitive Factors Influencing Encoding and Retrieval**

Emotion affects different aspects of cognition that are important to the successful encoding and retrieval of memory (Hamann, 2001; Talmi, 2013). Whereas emotion enhances ‘late’ long-term memory (LTM) through arousal-modulated consolidation, it can enhance ‘early’ LTM by facilitating other aspects of cognition (e.g., semantic relatedness and distinctiveness) that improve encoding and retrieval (Talmi, Luk, McGarry, & Moscovitch, 2007). Emotional stimuli may be easier to organize semantically and appear more distinct relative to neutral stimuli. This may facilitate the encoding of emotional stimuli compared to neutral stimuli presented close in time and may render emotional stimuli more easily accessible during retrieval,

thus resulting in an immediate memory advantage for emotional stimuli (Talmi, 2013). Item interrelatedness and distinctiveness have been shown to underlie emotional memory biases in tests of early LTM in young adults, but very little is known of their influence in older adults. These two cognitive factors should be well preserved in aging and might play a unique role in supporting the positivity bias in older adults.

**Role of Semantic Relatedness.** Memory is improved when stimuli are clearly organized within a schema or when they can be easily organized by identifying links between the items (Alba & Hasher, 1983). Organization helps processing the associations between items and encourages a more elaborative encoding of individual stimuli (Einstein & Hunt, 1980; R. R. Hunt & McDaniel, 1993). Likewise, stimuli that are more interrelated are more accessible during retrieval (Polyn, Erlikhman, & Kahana, 2011; Steyvers & Griffiths, 2008). This is relevant to work on EEM and the positivity effect because emotion provides a schema around which stimuli can be easily and coherently organized, and yet it is not often controlled in the majority of studies. For instance, pictures of a famished child, injured dog, and burning building are easier to link thematically than pictures of their neutral counterparts. This provides emotional stimuli with the additional benefit of being easier to associate with one another and to organize within a given schema, ultimately leading to a more elaborative encoding and easier retrieval (Einstein & Hunt, 1980; R. R. Hunt & McDaniel, 1993).

On the other hand, if stimuli are not selected carefully, the neutral items will often be unrelated with one another (e.g., blue mug, lightbulb, and buffalo). When neutral items are selected to have the same level of interrelatedness as emotional items, they are better recalled than unrelated-neutral items (Buchanan, Etzel, Adolphs, & Tranel, 2006; Talmi, Luk, et al., 2007; Talmi, Schimmack, Paterson, & Moscovitch, 2007) and sometimes even recalled to the

same extent as emotional items (Talmi & Moscovitch, 2004). These studies were all conducted with young adults, little to no work has been done in older adults. Despite the robust effects of organization on memory (Alba & Hasher, 1983), the semantic interrelatedness of emotional stimuli often remains uncontrolled and has not yet been thoroughly examined in older adults.

Emotional stimulus sets high in semantic relatedness may produce an immediate EEM effect in older adults that would otherwise not be present if the semantic interrelatedness of neutral stimuli was also high. Despite a possible associative memory deficit (Naveh-Benjamin, 2000), older adults' memory improves when they are presented with pairs of items that share pre-existing associations, possibly because no active elaboration is required of these items (Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003). Word pair relatedness increases memory in older adults without recruiting additional processing resources (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005). This demonstrates that older adults can exploit the greater organization of related word pairs to improve memory. The EEM effect in older adults may therefore result from their ability to automatically utilize pre-existing associations between emotional stimuli that are commonly absent in randomly selected neutral stimuli.

Semantic relatedness could also explain part of the positivity bias in older adults. Positive information might be considered more interrelated in memory than negative information (Koch, Alves, Krüger, & Unkelbach, 2016; Unkelbach, Fiedler, Bayer, Stegmüller, & Danner, 2008) because negative information has a greater representation in memory (Baumeister et al., 2001). This could make it easier for older adults to organize positive stimuli and later remember them better if the interrelatedness of items is not controlled. Young adults might not be affected by this inherent difference in the memory representation of positive and negative information because they can likely organize both types of information sufficiently well or adopt appropriate

strategies to do so (Naveh-Benjamin, Brav, & Levy, 2007), because they have more cognitive resources available to them. It is possible that studies showing a strong positivity bias in older adults might have used positive items that were more highly interrelated than the negative items. It is therefore conceivable that some of the variable findings in the positivity literature result in part from stimulus sets that do not control differences in interrelatedness between positive, negative, and neutral items.

The limited work on semantic relatedness and the positivity effect in aging may be due in part to the challenge of measuring item interrelatedness. Typically, what has been done in the past with picture sets (e.g., Talmi, Luk, et al., 2007) is to ask participants to rate each pair of pictures or words in a given category on their level of relatedness (i.e., for 20 positive pictures, there would be a total of 190 pairs to rate). Although several norms include measures of the semantic cohesiveness of words, there are currently no norms available for emotional images, despite pictures being commonly used in studies of emotional memory because of their greater arousal. Even less work has been done to control item interrelatedness in aging studies, leading this factor to be a potential confound in most of the emotional memory and aging literature.

**Role of Relative Distinctiveness.** Emotional stimuli are inherently more salient than neutral stimuli because of their greater ‘absolute’ significance (Schmidt, 1991). They contain unique attributes stored in long-term memory that are not shared by neutral items (compare a facial expression of pain to a neutral expression; Schmidt, 1991). When emotional and neutral items are presented close in time, the emotional items will stand out more relative to the neutral items and receive more processing priority. This is referred to as ‘relative’ distinctiveness. Both relative and absolute distinctiveness are separable: The absolute distinctiveness of a model wearing a dress is minimal, although its relative distinctiveness would be high if presented

alongside images of nude models (Schmidt, 2002). Although the images of nude models may contain absolute distinctiveness and naturally capture attention at encoding, the relative distinctiveness of the clothed model will also facilitate encoding and additionally provide a competitive advantage at retrieval. Relative distinctiveness therefore influences memory to a greater extent than absolute distinctiveness (Schmidt, 1991, 2002).

These effects of distinctiveness are generally confounded in research on EEM as emotional items are not only absolutely distinct, but are also relatively distinct when presented alongside neutral items in the same presentation block at encoding and recalled at the same time during retrieval. Although researchers often explain EEM in terms of the properties inherent in emotional stimuli (e.g., their high arousal or hedonic value), the EEM effect may be attributed in part to study designs that also increase their relative distinctiveness (i.e., their high arousal is distinct relative to low arousal neutral stimuli).

It would seem that relative distinctiveness influences the presence of the memory advantage for emotional information, at least in young adults. In young adults, emotional stimuli are remembered more often than neutral stimuli when they are presented together in the same mixed (i.e., emotion-heterogenous) blocks than when each emotion category is presented separately in unmixed (i.e., emotion-homogeneous) blocks (Dewhurst & Parry, 2000; Hadley & MacKay, 2006; Schmidt & Saari, 2007; Talmi, Luk, et al., 2007; Talmi & McGarry, 2012). Relative distinctiveness is also important during retrieval because the memory advantage for emotional stimuli appears when items are recalled together at the same time but disappears when they are recalled separately (McDaniel, Dornburg, & Guynn, 2005). This shows that even if emotional stimuli have an ‘absolute’ significance, they are not always remembered more often than neutral stimuli. When each type of stimulus is studied/tested separately in unmixed blocks,

this removes the relative distinctiveness of emotional items which subsequently reduces or eliminates the memory advantage for emotional items.

Very little work has explored the influence of relative distinctiveness on the presence of the positive memory bias in aging. In general, older adults tend to prioritize the processing of positive stimuli over other stimuli. They look more toward positive stimuli than toward negative or neutral stimuli (Isaacowitz, Allard, et al., 2009). This is accompanied by changes in the recruitment of amygdala and frontal regions during the encoding of positive information (Cacioppo et al., 2011; Dolcos et al., 2002; Mather et al., 2004; St. Jacques et al., 2009). The attention and memory biases toward positive information may reflect controlled cognitive processes that serve to regulate emotions (Allard & Kensinger, 2017; Isaacowitz, Toner, & Neupert, 2009). Yet it remains unknown whether these behavioural and neural responses depend on the relative distinctive processing of positive stimuli and if they would still occur when relative distinctiveness is removed.

Relative distinctiveness seems to improve older adults' memory for neutral items (the von Restorff or isolation effect), but perhaps not to the same extent as in young adults (Bireta, Surprenant, & Neath, 2008). Only a handful of studies have considered relative distinctiveness in the aging memory positivity literature, and the results are unclear. Some work has directly compared the effects of using mixed and unmixed sets of pictures (Grühn, Scheibe, & Baltes, 2007) and words (Grühn, Smith, & Baltes, 2005). In neither of these studies did older adults show a positive memory bias, and in fact, they showed a negativity bias for words when relative distinctive processing was available (i.e., in the mixed sets; Grühn et al., 2005). A number of limitations might reduce the generalizability of these findings (Grühn et al., 2005), such as the use of less emotionally-eliciting material (e.g., words instead of pictures), multiple-trial free

recall (involving exposure to the same words 5 times), and different presentation times for each age group.

If distinctive processing underlies the positivity effect in older adults, then positive stimuli should only receive processing priority over negative and neutral stimuli when they are studied/tested together in mixed lists. When each emotion is studied/tested in separate, unmixed lists then all items should be processed equally well because there is no longer competition between the different kinds of emotional stimuli. This should reduce or completely eliminate a positive memory bias in older adults by allowing negative and neutral stimuli equal opportunity to be studied and recalled accurately. If this is the case, distinctive processing might be the fundamental cognitive process that allows for the expression of a positive memory bias in older adults and it is within a researcher's ability to control in their experimental design. To my knowledge, there is currently no study that has examined whether both relative distinctiveness and semantic relatedness together can explain how the positive memory bias is produced in older adults.

### **Mood-Congruent Memory (Intrinsic Factor)**

Once we understand the experimental and cognitive conditions required to produce a positivity bias, we can then ask why does the bias occur in older adults specifically? Are there possible confounds in past research that are not specific to aging that could explain the positivity bias? As a possible answer to these questions, I explore whether inherent differences in mood between young and older adults can explain these commonly observed differences in memory.

### **Conditions for Mood Congruence**

Conceptually, mood is considered to be a prolonged emotional state, not always attributed to a specific event (vs. the brief experience of an emotion; Rottenberg, Ray, & Gross, 2007). Prolonged emotional states (or moods) can influence how brief emotional experiences are processed and later remembered. Therefore, mood might affect how one reacts to the brief presentation of an emotional stimulus (e.g., picture or word) during a typical emotional memory experiment. Although many terms are used in the literature—mood, emotion, and affect—these can be considered synonymous because they all describe “the same mental states that arise spontaneously and generally involve subjective experience, physiological reactions, and behavioral components” (Knight, Rastegar, & Kim, 2016, p. 280). Throughout this thesis, these terms are used interchangeably based on the linguistic context.

Generally speaking, a person’s mood can influence different aspects of cognition, including memory (for reviews, see Blaney, 1986; Bower, 1987; Eich et al., 2008). This is because information that is emotionally congruent with a person’s mood may receive greater attention and more elaborative processing than neutral or emotionally-incongruent material (Eich et al., 2008). For instance, when a person is in a positive mood, they may pay more attention to and remember positive information better than they would negative or neutral information. In contrast, they may remember negative information more often when they are also in a negative mood. Findings of mood-congruent memory are prevalent in the literature and are commonly reported in people with depression and anxiety, including both young and older adults (for review, see Knight, Rastegar, & Kim, 2016). This congruence between mood and cognition is not specific to memory but is shown in a range of behaviours (Forgas & Bower, 1987; Knight et al., 2016), suggesting it is a widely observed phenomenon.

It is important to note that there are at least four different ways in which mood could match the affective nature of stimuli (for a review, see Singer & Salovey, 1988). First, memory increases when mood during encoding is similar to mood during retrieval. Second, memory is improved when mood during encoding matches the affective tone of the material (encoding congruence). Third, memory is improved when mood during retrieval matches the affective tone of the material. And finally, stimuli are better recalled as the intensity of a mood increases. Although all four conditions may affect memory, the second leads to the most robust findings (Singer & Salovey, 1988). As stated by Bower (1987), encoding congruence “means that stimuli whose affective significance matches the person’s emotional state will provoke greater attention, faster perception, and more elaborate processing, with the result that those stimuli will be learned better than neutral or mood-incongruent materials. It is as if [participants] are biased to attend to stimuli that justify and maintain their emotional state” (p. 444). As such, mood during encoding is most likely to produce the strongest mood-congruent memory effects.

### **Theoretical Explanation**

According to the associative network theory of emotion (Bower, 1981), mood is represented in memory as a node like any other, which means that being in a particular mood will activate its corresponding node and similar nodes in the network (Eich et al., 2008). This leads to the selective priming of concepts, thoughts, and memories related to that emotional state. The effect of mood induction and priming will be greatest when the task requires an extensive, open-ended information search (e.g., free recall) because the primed nodes will be preferentially retrieved during the memory test.

The Affect Infusion Model (AIM; Forgas, 1995, 2002) further describes four different types of processing strategies that a participant may adopt during any given task that predict the

strength of mood congruence: Congruence is expected to be weakest when information processing is simple and requires little effort, and strongest when processing is elaborative, demanding, and complex (Eich et al., 2008). The first type of processing strategy is a *direct access* strategy that is used when one is particularly familiar with the task or stimuli at hand, and has already stored knowledge on how to respond to the task. For example, when making judgments about well-known people, participants are simply required to retrieve their previously stored judgment about the person (providing they are familiar with him or her), and to respond based on this pre-existing response (Eich et al., 2008). When engaging in *motivated* processing, participants will respond in accordance with an external motivator rather than producing a response based on their current emotional state. For example, if asked to judge how you feel towards a company that you are currently interviewing with, you will be motivated to give the most positive response regardless of how you currently feel. No congruence is expected when engaging in motivated or direct access processing as these kinds of strategies are simple and depend on a specific processing goal. On the contrary, congruent effects would be expected when participants process information based on a *heuristic* strategy centered on how they feel. In this case, participants would rely on their current affect to guide their responses when their processing resources are otherwise limited. The fourth type of strategy, *substantive* processing, is the most elaborative and demanding type of processing strategy (Eich et al., 2008). Participants engage in substantive processing when faced with a novel or challenging task that requires time and adequate resources to process.

The associative network theory and AIM model are consistent with the general finding that the positivity effect is more likely to occur when using more demanding memory tasks, such as free recall, than when using simpler designs of yes-no or forced choice recognition tasks

(Charles et al., 2003). Free recall can be thought of engaging more substantive processing, the fourth and more elaborative processing strategy, because participants must actively retrieve information from memory. This is in contrast to recognition tasks whereby stimuli are presented twice and participants must simply decide whether a stimulus matches a representation in memory (i.e., a more direct access strategy corresponding to the first level of processing in the AIM model).

### **How Could Mood Congruence Explain the Positivity Effect?**

Mood can alter attention to and memory for emotional stimuli. It can influence the direction of the emotional memory bias by preferentially enhancing memory for either positive or negative material, depending on what is congruent with a person's mood. This would suggest that participants who differ in their mood at encoding, might also differ in their emotional memory bias. Indeed, older adults seem to be generally more satisfied with life and in a more positive mood than young adults. For example, there appears to exist an overall U-shaped relationship between age and subjective well-being, where the greatest decline in well-being is observed in middle-age (45-54 years), after which point it continues to increase into older age (for a review, see Steptoe, Deaton, & Stone, 2015). More specifically, cross-sectional and longitudinal studies have found that life satisfaction (Gana, Bailly, Saada, Joulain, & Alaphilippe, 2013) and positive affect increase with age (Gana, Saada, & Amieva, 2015; Kunzmann, Little, & Smith, 2000), and negative affect decreases with age, even when controlling for potential health constraints (Kunzmann et al., 2000).

A similar pattern exists in the positivity effect in aging memory literature: Older adults in previous studies have consistently reported being in a more positive mood than young adults at the start of experiments. A number of studies have reported higher positive affect and lower

negative affect (commonly measured using the Positive and Negative Affect Schedule; Watson et al., 1988) in older adults when compared to young adults (Emery & Hess, 2008, 2011; Fernandes et al., 2008; Fung et al., 2010; Mather & Knight, 2005; Tomaszczyk et al., 2008), and other studies have reported differences only in positive affect (Mather & Knight, 2005) or negative affect (e.g., Charles, Mather, & Carstensen, 2003<sup>2</sup>; Grühn, Scheibe, & Baltes, 2007; Spaniol, Voss, & Grady, 2008<sup>3</sup>). Studies that have included measures of depressive symptomatology (e.g., Geriatric Depression Scale or the Centre for Epidemiologic Studies Depression Scale) found that older adults reported fewer depressive symptoms than young adults (e.g., Charles et al., 2003; Fung et al., 2010; Mather & Knight, 2005; Mickley & Kensinger, 2009).

Age differences in baseline mood might be further exacerbated by the frequent use of university students as the young adult reference group. Researchers commonly recruit young adults from undergraduate research pools because it is a convenient, cost-effective way to recruit participants. Yet, findings from university students may not always generalize well to the wider community. This may be of particular concern in emotion and memory research because university students have been shown to experience higher levels of psychological distress than age-matched adults from the community (Adlaf, Gliksman, Demers, & Newton-Taylor, 2001), which could alter their emotion processing and memory. On the other hand, past studies might have included the most active and motivated older adults because they are the ones who are most likely to respond to study advertisements. This could mean that there is a general recruitment bias whereby researchers over recruit the most positive older adults and the least positive young

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<sup>2</sup> Experiment 2 (mood was not measured in experiment 1).

<sup>3</sup> Experiments 1 and 2.

adults. Indeed, previous studies that recruited both young and older adults from the wider community reported no difference in positive affect (Charles et al., 2003; Grühn et al., 2007; Spaniol et al., 2008), and no positivity effect (Charles et al., 2003; Grühn et al., 2007; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Pruis, Neiss, Leigland, & Janowsky, 2009; Spaniol et al., 2008), further highlighting the importance of considering recruitment practices and mood differences in work on emotional memory and aging.

Surprisingly very little research has directly examined the influence of mood on the positivity effect. Some work suggests that increased attention toward positive stimuli correlates with increased positive mood in both young and older adults (Allard & Kensinger, 2017). In memory studies, there is some evidence of mood congruence in older adults using mood induction and tests of implicit memory and autobiographical memory (for review, see Knight et al., 2016). In one study of early LTM (Knight, Maines, & Robinson, 2002), young and older adults completed a sad or neutral mood induction protocol (using sentences and music) prior to completing a word memory task. When older adults were in a sad mood, they recalled fewer positive words than when they were in a neutral mood. However, the sad mood induction did not alter the immediate recall of negative words in either young or older adults. This provided partial support for the mood-congruent hypothesis. In other studies, researchers examined the influence of mood on the positivity effect by including mood as a covariate in their analyses. So far, the results are divergent and inconclusive. Mood has sometimes correlated with memory (Barber et al., 2016; Charles et al., 2003), and mediated some of the effects of age on memory (Emery & Hess, 2008), whereas other times it did not (Fernandes et al., 2008; Mather & Knight, 2005; Tomaszczyk et al., 2008). Past procedures vary enormously (e.g., encoding task/instructions, memory test delay and type) as do their support for or against the positivity effect.

The influence of mood on the positivity effect in aging remains unclear. According to the mood-congruent hypothesis, a positivity bias appears in older adults because they are in a positive mood at encoding compared to young adults who are more likely to be in a negative mood and demonstrate a negativity bias. However, if mood in young and older adults is experimentally manipulated, then both age groups should show increased memory for positive stimuli (relative to negative and neutral stimuli) when in a positive mood, and increased memory for negative stimuli (relative to positive and neutral stimuli) when in a negative mood. This would provide strong evidence that differences in mood is why older and young adults often show differences in emotional memory.

### **Studying Mood in the Laboratory**

Experimentally manipulating mood is a useful technique to minimize interindividual differences in naturally occurring moods. Mood is commonly studied by eliciting a target mood (positive, negative, or neutral) through the use of sentences (Velten technique), film, music, hypnosis, imagination, gift, or a combination of these techniques; although films have become one of the most common and efficient mood induction techniques (for reviews of different methods, see Gerrards-Hesse, Spies, & Hesse, 1994; Gilet, 2008; Westermann, Stahl, & Hesse, 1996). This is because films are high in ecological validity, easy to standardize, and are able to elicit emotions at subjective and physiological levels longer than most other types of emotional stimuli (Carvalho, Leite, Galdo-Álvarez, & Gonçalves, 2012; Fernández-Aguilar, Ricarte, Ros, & Latorre, 2018). Despite the usefulness of mood induction protocols, it can still be challenging to reliably elicit positive emotions (Beaudreau, MacKay, & Storandt, 2009; Fernández-Aguilar et al., 2018). Moreover, very little work has been done to evaluate the effectiveness of mood induction protocols in older adults (Fernández-Aguilar et al., 2018). Although differences may

exist in the emotional responses of young and older adults (Beaudreau et al., 2009), films can effectively elicit a range of emotions in older adults too (Fernández-Aguilar et al., 2018).

Moreover, older adults seem more likely to maintain their positive or negative mood throughout an experiment compared to the majority of young adults who seem to return to a neutral state within 14 minutes of a task (Stanley & Isaacowitz, 2011). Very little work has tested older adults using positive mood induction, yet this would be a useful technique for studying the effects of mood on aging memory.

### **Thesis Studies**

In this thesis, I examine whether certain factors partially independent of aging might influence the presence and magnitude of the positivity bias in memory. In Study 1, I consider two extrinsic factors (item interrelatedness and distinctiveness) from the emotion-enhanced memory literature to explain *how* the positivity bias occurs. Item interrelatedness and distinctiveness have been shown to support emotion-enhanced memory in early LTM in young adults, and may therefore explain the cognitive processes required to produce a positivity bias in older adults. I apply what is learned in this first paper to the methodological designs of Studies 2 to 4. In these latter studies, I facilitate the distinctive processing of stimuli to increase the likelihood of observing a positivity bias and its possible interaction with mood. As an intrinsic factor, mood might help explain *why* a positivity bias frequently occurs in older adults but not in young adults. These two age groups tend to differ in their mood at the start of experiments, possibly influencing their memory. Together, these papers help explain how and why a positive memory bias might appear in aging.

## **Experimental Manipulations**

In Study 1, I manipulate the semantic relatedness and relative distinctiveness of pictures to test whether older adults' emotional memory can be explained by these two factors. More specifically, I examine whether relative distinctiveness is necessary to produce a positivity bias in older adults by testing the presence of the bias in conditions with and without distinctive processing, and compare these results to a sample of university students.

Studies 2 to 4 explore possible effects of mood on memory. First, in Study 2A, I develop and validate a set of emotional and neutral videos that are naturalistic and selected from unfamiliar sources (i.e., not mainstream films), focusing on videos that are likely to be relevant for both young and older adults. I use these videos in Study 2B to experimentally manipulate mood and to test whether differences in mood predict differences in emotional memory bias in young and older adults.

In Studies 3 and 4, I further test the effects of mood on the positivity bias beyond any age-specific factors, by examining young adults only. This serves to eliminate any possible uncontrollable confounds that exist between age groups (e.g., changes related to neurocognitive decline) which might mask the interactions between mood and memory. In Study 3, I use a written priming task, to experimentally manipulate mood and time perspective in young adults. This priming task is similar to the one used in Barber et al. (2016) that specifically examined the effects of time perspective on memory but did not experimentally manipulate mood. In Study 4, I take a naturalistic approach to studying the effects of mood on memory by comparing possible differences between two separate young adult samples: university students and non-students.

## **Memory Task**

In all studies, memory is measured using immediate free recall of positive, negative, and neutral pictures. The pictures are extensively piloted in advance to determine their level of valence, arousal, and semantic relatedness. The three phases of the memory task (encoding, delay, retrieval) are generally the same across experiments and rigorous scoring and statistical methods are used to validate the free recall responses (including blind rating, double or triple ratings, and measures of Pearson's correlations or Cohen's kappa where appropriate). There is some variation in the encoding instructions (intentional or incidental) and the total number of pictures to meet the needs of each particular study (see Table 2).

The memory task is identical in Studies 1 and 4 (intentional encoding, 16 pictures per category, 4 categories of pictures), and in Studies 2B and 3 (incidental encoding, 10 pictures per category, 3 categories of pictures). Study 1 is designed to assess the contribution of item interrelatedness and distinctiveness based on previous work (Talmi, Luk, et al., 2007; Talmi & McGarry, 2012). Study 4 uses the same design as in Study 1 in order to directly compare results across the two studies, because neither of them include a mood manipulation. The memory task is slightly modified for Studies 2B and 3, to better measure the effects of mood on the positive memory bias. To do so, incidental encoding instructions are used to promote the most naturalistic, unconstrained type of processing because this is more likely to produce a positivity bias (Reed et al., 2014). As a consequence, the total number of pictures and picture categories is reduced to avoid floor effects. These sound methodological procedures help to answer the question of how and why a positivity bias might occur in aging.

Table 2

*Summary of Methodological Design in Thesis Studies*

<b>Study</b>	<b>Factors</b>	<b>Experimental Manipulations</b>	<b>Sample</b>	<b>Encoding</b>	<b>Number of Stimuli</b>	<b>Picture Categories</b>
1	Semantic relatedness and distinctiveness	Interrelatedness of neutral items and distinctiveness of emotional items	University students and older adults	Intentional	16 pictures per category	Positive, negative, related-neutral, unrelated-neutral
2A	Video validation	Selection of videos ranging in valence and arousal	University students	-----	29 videos	-----
2B	Mood	Mood manipulation using videos	University students and older adults	Incidental	10 pictures per category	Positive, negative, related-neutral
3	Mood and time perspective	Mood and time manipulation using texts	University students	Incidental	10 pictures per category	Positive, negative, related-neutral
4	Mood	Naturally-occurring moods in two young adult samples	Young adult students and non-students	Intentional	16 pictures per category	Positive, negative, related-neutral, unrelated-neutral

**CHAPTER 2. RESEARCH ARTICLES**

**Study 1. Semantic Relatedness and Distinctive Processing May Inflate Older Adults’  
Positive Memory Bias**

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### Abstract

Emotional stimuli are often more semantically interrelated and relatively distinct than neutral stimuli. These factors can enhance memory for emotional stimuli in young adults, but their effects in older adults—and on the age-related positive memory bias—remain unknown. In the present article, we tested whether item relatedness and distinctiveness affect emotional memory in young adults (Experiments 1 and 2) and the positive memory bias in older adults (Experiment 2). In both experiments, participants studied positive, negative, and neutral pictures and performed free recall after 1 min and 45 min. To manipulate relatedness, the neutral pictures were either as highly interrelated as the emotional pictures ('related neutral') or lower in semantic relatedness ('unrelated neutral'). To manipulate distinctiveness, we had participants process the emotional pictures in either a relatively distinct manner (mixed condition), by studying emotional and neutral pictures at the same time, or in a non-distinctive manner (unmixed condition), by studying and recalling each picture category separately. Overall, higher semantic relatedness (i.e., related-neutral vs. unrelated-neutral pictures) increased memory in both age groups. Distinctiveness did not affect memory in young adults, but it did alter the positive memory bias in older adults. Older adults recalled more positive than negative pictures when the pictures were processed in mixed sets, but not when they were processed in unmixed sets. These findings were consistent across both test delays. This suggests that previous reports, which were often based on mixed designs in which item interrelatedness was not controlled, may have overestimated the size and/or robustness of the positivity bias in older adults.

*Keywords:* aging, emotion, positivity effect, semantic relatedness, distinctiveness

## Introduction

In real life, the most powerful episodic memories tend to be emotional (e.g., events of a wedding day or funeral). Likewise, in the laboratory, participants remember emotional information more often than neutral information (i.e., emotion-enhanced memory [EEM]; Ack Baraly, Hot, Davidson, & Talmi, 2017). However, young and older adults generally differ in their emotional memory biases: Whereas young adults often preferentially remember negative (vs. positive) information, older adults often preferentially remember positive (vs. negative) information (Carstensen & DeLiema, 2018; Reed, Chan, & Mikels, 2014). Researchers have attributed this ‘positivity effect’ in aging to lifespan changes in motivation (Carstensen et al., 1999; Mather & Carstensen, 2005), in cognitive-affective complexity (Labouvie-Vief, 2003; Labouvie-Vief, Grünh, & Studer, 2010), and/or in neural anatomy/function (Cacioppo et al., 2011; Dolcos et al., 2002; St. Jacques et al., 2009). The positivity effect in aging memory continues to be controversial, however (Grünh et al., 2016; Kan et al., 2017). The positivity effect is usually found using brief study-test delays of less than 1h (e.g., Charles, Mather, & Carstensen, 2003). At such brief delays, several cognitive factors might influence the EEM by altering encoding and retrieval processes (Ack Baraly et al., 2017; Bennion, Ford, Murray, & Kensinger, 2013; Hamann, 2001; Talmi, 2013). Semantic relatedness and relative distinctiveness are two cognitive factors that could influence early EEM (i.e., EEM tested within a brief delay)<sup>4</sup>, but these factors have rarely been addressed in the aging positivity effect literature. In the present article, we examine whether semantic relatedness and distinctive processing can explain emotional memory biases in young and older adults.

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<sup>4</sup> In contrast to early EEM, “late EEM” is tested after longer delays of hours or days and is largely explained by arousal-mediated consolidation (McGaugh, 2004).

### **Semantic Relatedness**

If not chosen carefully, the emotional stimuli in a memory study can be more interrelated and easier to organize semantically than the neutral stimuli (Talmi & Moscovitch, 2004). That is, participants might identify thematic links among the emotional stimuli (e.g., pictures of a *shark*, *bandage*, and *ambulance*) more readily than among the neutral stimuli (e.g., pictures of a *dolphin*, *handkerchief*, and *bus*). This will render the emotional stimuli easier to organize within a given schema, ultimately leading to more elaborative encoding and easier retrieval (Einstein & Hunt, 1980; R. R. Hunt & McDaniel, 1993). Consequently, sets of emotional stimuli that are highly interrelated could result in an immediate EEM effect that would otherwise not be present if the neutral stimuli were also highly interrelated (C. Hunt, Trammel, & Krumrei-Mancuso, 2015; Talmi & Moscovitch, 2004). Indeed, many EEM studies with young adults have used two sets of neutral stimuli: a randomly selected “unrelated-neutral” set, in which item interrelatedness is generally low, and a “related-neutral” set, in which item interrelatedness is high and equal to that of the emotional stimulus set(s). Usually, the young adults remember a greater number of neutral stimuli from the high–than from the–low relatedness sets (Buchanan et al., 2006; Talmi, Luk, et al., 2007; Talmi, Schimmack, et al., 2007), sometimes remembering just as many related-neutral as emotional items (Talmi & Moscovitch, 2004). In older adults, memory for neutral word pairs improves when the pairs are related as compared to when they are unrelated. In fact, semantic relatedness can be so helpful to older adults that this can attenuate the typical age-related memory decreases seen with unrelated-neutral stimuli (Naveh-Benjamin et al., 2005, 2003).

Older adults’ EEM may therefore result in part from their ability to automatically utilize pre-existing semantic associations (Naveh-Benjamin et al., 2005) between emotional stimuli,

which would provide an encoding and/or retrieval advantage over unrelated-neutral stimuli. But inherent differences could also exist between the interrelatedness of positive and negative stimulus sets, that when uncontrolled, lead to the positivity bias in older adults. For instance, positive information might be more tightly clustered and interrelated in memory than negative information (Koch et al., 2016; Unkelbach et al., 2008), because of negative information's greater (Baumeister et al., 2001) – yet more diverse – representation in memory. Older adults could more easily discern the semantic organization of positive stimuli and ultimately remember them better, when the semantic relatedness of the stimulus sets is not controlled. This might affect young adults to a lesser extent because they likely have sufficient resources to organize both types of information and/or to adopt appropriate strategies (Naveh-Benjamin et al., 2007). Consequently, the variability across existing findings on the aging positivity effect in memory might have something to do with differences from study-to-study in stimulus selection across the emotional and neutral item sets. For instance, those articles showing a particularly strong positivity effect in memory might have included positive stimuli that were highly interrelated, or negative stimuli that were slightly less so. Yet, the interrelatedness of emotional and neutral stimuli remains generally uncontrolled in the aging positivity-effect literature.

### **Distinctiveness**

The relative distinctiveness of emotional stimuli might also contribute to EEM. Emotional stimuli are inherently more salient than neutral stimuli, in the sense that they have a greater “absolute” significance because of their unique attributes stored in long-term memory (e.g., compare a facial expression of pain to a neutral expression; Schmidt, 1991). But emotional stimuli are also distinct in a “relative” sense, because they are often more salient than other, neutral stimuli presented close in time. Relative distinctiveness might influence memory to a

greater extent than absolute distinctiveness (Schmidt, 1991, 2002). The EEM effect is commonly explained by the properties inherent to emotional stimuli (e.g., their high arousal; McGaugh, 2004), but it may also be due in part to the use of study designs that increase the relative distinctiveness of emotional items. Indeed, young adults' EEM seems greater when emotional and neutral items are studied/tested together in mixed (i.e., emotion-heterogeneous) lists than when each emotion category is studied/tested separately in unmixed (i.e., emotion-homogeneous) lists (Dewhurst & Parry, 2000; Hadley & MacKay, 2006; McDaniel et al., 2005; Schmidt & Saari, 2007; Talmi, Luk, et al., 2007; Talmi & McGarry, 2012). The unmixed study lists reduce the relative distinctiveness of the emotional stimuli, by presenting emotional and neutral items in isolation from one another, which subsequently reduces EEM.

Few aging studies have used unmixed designs (e.g., Emery & Hess, 2011) or have directly contrasted unmixed and mixed sets of stimuli (e.g., Grühn, Scheibe, & Baltes, 2007; Grühn, Smith, & Baltes, 2005). Interestingly, none of the authors just listed reported a positivity bias in older adults. In fact, one of these studies (Grühn et al., 2005) showed that increasing relative distinctiveness improved older adults' memory for negative words. To our knowledge, currently no study has considered both item interrelatedness and distinctiveness when examining older adults' positivity bias. The effects of relative distinctiveness on semantically matched negative, positive, and neutral pictures remain unclear. Although several behavioral (Isaacowitz, Allard, et al., 2009; Isaacowitz et al., 2006b) and neural (Cacioppo et al., 2011; Dolcos et al., 2002; Mather et al., 2004; St. Jacques et al., 2009) studies have suggested that older adults prioritize positive stimuli, it is possible that these differences are only present when the positive stimuli are relatively distinct as compared to the other stimuli. If distinctive processing underlies the positivity effect in older adults, then positive stimuli should receive particularly high

processing priority when test items are presented together in mixed sets. In contrast, all emotional and neutral stimuli should be processed equally well when they are presented in separate unmixed sets, thus attenuating or even abolishing older adults' positive memory bias. In other words, the positivity bias in older adults might result from a temporary, contextual advantage given to positive information when it is processed in relation to other information, rather than from a permanent and absolute memory decrease for negative information.

### **Present Study**

The aim of this study was to examine whether semantic relatedness and relative distinctiveness can explain emotion-enhanced memory in young adults, and more specifically, the positivity bias in older adults. In Experiment 1, we performed a conceptual replication of Talmi, Luk, et al. (2007), who found that both semantic relatedness and relative distinctiveness influenced young adults' memory for negative and neutral pictures. To build on their work, we also tested memory for positive pictures (which were absent from their original study) in a sample of young adults in Canada. In Experiment 2, we used the same experimental design with young and older adults in France.

To examine item interrelatedness, neutral pictures were either low (unrelated neutral) or high (related neutral) in semantic relatedness—that is, interrelated to an extent similar to that in emotional pictures. In addition, participants processed the emotional pictures in either a distinctive manner (mixed condition), with all items studied together, or a nondistinctive manner (unmixed condition), in which each picture category was studied and recalled separately (similar to Talmi, Luk, et al., 2007). We expected participants to recall more emotional pictures when these were more highly interrelated or more relatively distinct than the neutral pictures (Talmi, 2013; Talmi & McGarry, 2012). Furthermore, we predicted that relative distinctiveness would

influence the presence of young adults' EEM and older adults' positivity bias. More specifically, we expected that young adults (Experiments 1 and 2) would recall more emotional pictures than related-neutral pictures in the mixed condition, but not in the unmixed condition, when distinctiveness was controlled. We also expected young adults to remember more negative than positive pictures in the mixed condition only. In contrast, we expected older adults (Experiment 2) to show a positive memory bias in the mixed condition, which would disappear or become weaker in the unmixed condition. Both age groups were always expected to remember more emotional pictures than unrelated-neutral pictures (i.e., the classic EEM pattern), regardless of distinctive processing.

A final consideration was the influence of recall delay, which occurred 1 min and 45 min after picture presentation. The 1-min delay (replicating Talmi, Luk, et al., 2007) was long enough to test for early EEM (Talmi, Grady, Goshen-Gottstein, & Moscovitch, 2005) and all of our research hypotheses, while ensuring high recall rates in the older adults. The 45-min delay was more exploratory. Some research has suggested that EEM is stronger when it is tested over a delay (Yonelinas & Ritchey, 2015) and that older adults' positivity bias could be strengthened by repeated testing (Mather & Knight, 2005). We included two relatively brief intervals in order to examine these effects on early EEM in young and older adults.

### Experiment 1

In Experiment 1 we examined whether Canadian university students' early EEM could be accounted for by semantic relatedness and distinctive processing. The experimental conditions and procedures were similar to those used in Talmi, Luk, et al. (2007, Exp. 1), with the addition of a positive picture category. We expected students to remember more emotional than neutral

pictures, but only when the emotional pictures were more interrelated and/or were relatively distinct. Furthermore, we expected students to remember more negative than positive pictures when the items were processed in mixed sets.

## **Method**

### **Participants**

Forty-seven young adults (under 35 years old) were randomly assigned to either the mixed ( $n = 24$ ; 20 women, four men; mean age = 19.67 years) or unmixed ( $n = 23$ ; 20 women, three men; mean age = 19.57 years) condition. The participants were University of Ottawa students who received course credit for participating. All provided written informed consent and completed the tasks in their choice of English or French. Data from an additional four participants were excluded because of a visual memory impairment, current drug abuse, incomplete study session, and incomplete data due to microphone error. Participants were further screened for high levels of depressive symptomatology based on the z-score distribution of the Centre for Epidemiologic Studies Depression scale (Radloff, 1977), which resulted in no additional exclusions. This study was approved by the University of Ottawa Research Ethics Board (#H12-14-14).

### **Stimuli**

The target images consisted of 16 positive, 16 negative, 16 related-neutral and 16 unrelated-neutral pictures. The related-neutral pictures depicted domestic scenes of people, objects, or scenes around the house (e.g., man painting a room, ironing board, or backyard), whereas the unrelated-neutral pictures had no obvious thematic link (e.g., blue mug, buffalo, or outdoor staircase). Approximately one-third of the pictures in each category portrayed people,

and the remaining pictures illustrated objects, animals, or outdoor landscapes. An additional 16 pictures (four per category) were chosen as buffer images. Some of the negative, related-neutral, and unrelated-neutral pictures were drawn from Talmi and McGarry's (2012) collection, but others, in addition to the positive pictures, were selected from the International Affective Picture System (P. J. Lang, Bradley, & Cuthbert, 2008), the Geneva Affective Picture Database (Dan-Glauser & Scherer, 2011), and the internet.

We conducted a pilot study with 12 university students (nine women, three men; mean age = 19.08 years) to determine the average valence, arousal, and semantic interrelatedness of the pictures (Table 3). One additional participant was excluded because of brief response times (< 10 ms). During the pilot study, participants saw each of the 64 pictures (i.e., 16 pictures/category) one at a time in a randomized order and reported their feelings of valence, from 1 (happy) to 9 (unhappy), and arousal, from 1 (excited) to 9 (calm), using the Self Assessment Manikins from P. J. Lang et al. (2008)<sup>5</sup>. Next, participants rated, in random order, the semantic interrelatedness of all possible pairs of pictures from the same category (i.e., 120 negative pairs, 120 positive pairs, etc.) from 1 (not at all related) to 7 (extremely related), concentrating on picture content rather than physical similarity, as per Talmi and McGarry (2012). The mean relatedness was calculated for each picture by averaging all relatedness scores between that picture and the 15 other pictures from the same category. The mean valence, arousal, and semantic relatedness of each picture were averaged across all participants and analyzed with separate univariate analyses of variance (ANOVAs), with Picture Type (negative, positive, related neutral, unrelated neutral) as the between-item variable. The ANOVAs showed

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<sup>5</sup> We used the same pictorial scale from P. J. Lang et al. (2008), but inverted the numbers assigned to each extreme to maintain the spatial coherence between the pictorial scale and the keyboard used for input.

Table 3

*Mean (SD) Ratings for Pictures Used in Experiments 1 and 2*

	Negative	Positive	Related-neutral	Unrelated-neutral
<i>Experiment 1</i>				
Valence	7.77 (0.57)	2.10 (0.41)	4.65 (0.58)	4.68 (0.78)
Arousal	2.72 (0.75)	3.48 (1.07)	5.86 (0.49)	5.49 (0.69)
Relatedness	3.97 (0.38)	3.70 (0.32)	4.15 (0.32)	2.24 (0.17)
<i>Experiment 2</i>				
<i>Young Adults</i>				
Valence	7.99 (0.54)	2.53 (0.43)	5.13 (0.69)	5.16 (0.42)
Arousal	4.12 (0.49)	3.61 (0.71)	6.53 (0.49)	6.09 (0.65)
Relatedness	3.59 (0.71)	3.34 (0.40)	4.07 (0.50)	1.54 (0.16)
<i>Older Adults</i>				
Valence	7.80 (0.88)	2.64 (0.75)	4.73 (0.50)	4.90 (0.48)
Arousal	2.32 (0.64)	4.67 (1.42)	5.06 (1.11)	4.80 (0.83)
Relatedness	4.44 (0.59)	3.96 (0.33)	4.03 (0.44)	2.53 (0.21)

*Note.* Valence was rated from 1 (happy) to 9 (unhappy), arousal from 1 (excited) to 9 (calm), and relatedness from 1 (not at all related) to 7 (extremely related).

that the four picture types differed significantly in valence [ $F(3,60) = 240, p < .0001$ ], arousal [ $F(3,60) = 61, p < .0001$ ], and semantic relatedness [ $F(3,60) = 128, p < .0001$ ]. Planned contrasts with Bonferroni corrections showed that all pictures differed in valence ( $ps < .0001$ ), except for the two neutral categories ( $p > .999$ ). Negative pictures were more arousing than positive pictures ( $p = .044$ ), and both were more arousing than neutral pictures ( $ps < .0001$ ). Related-neutral and unrelated-neutral pictures were matched in arousal ( $ps > .999$ ). Each picture category therefore represented the expected emotional valence, and the emotional pictures were more arousing than the neutral pictures. Crucially, the negative, positive, and related-neutral pictures

were all more highly interrelated than the unrelated-neutral pictures ( $ps < .0001$ ). The negative pictures were matched in relatedness with the positive ( $p = .102$ ) and related-neutral ( $p = .593$ ) pictures, but the related-neutral pictures were more interrelated than the positive pictures ( $p = .001$ ).

## Procedures

Each session began with the written informed consent, followed by the memory task, based on that of Talmi, Luk, et al. (2007), which included three parts: intentional encoding, arithmetic questions, and free recall. During the encoding task, participants studied pictures that appeared in a random order on a computer screen. Each picture appeared for 2 s, followed by a blank screen for 4 s. We instructed participants to memorize as many pictures as possible and included no interfering task, in order to minimize the effects of unequal attention allocation on memory (Talmi & McGarry, 2012). Once all pictures of that block had been presented, participants then completed short arithmetic problems involving addition, subtraction, multiplication, or division, for 1 min (e.g., which equation produces the higher value “15+39” or “25+18”?). This distraction task ensured that memory performance would reflect early long-term memory, by displacing items from working memory (Talmi et al., 2005). Immediately after, participants described the pictures they could remember from the previous study block, in any order and with enough detail so that the experimenter could identify the picture. The experimenter recorded the participants’ responses for 3 minutes using an audio recorder. Once recall was done, participants started over again with a new set of pictures. There were four blocks in total, each containing 16 targets and four buffers (two before and two after the targets). The buffers minimized the effects of primacy and recency on memory. In the unmixed condition, the targets and buffers in each block were from the same category of pictures. In the mixed

condition, four targets were randomly selected from each category, and the buffers were chosen randomly. Participants familiarized themselves with the task procedures by completing a practice session with four neutral pictures at the start of the experiment. The memory task was run using E-Prime 2.0 software.

After the memory task, participants completed a demographics form, health questionnaire, and the Centre for Epidemiologic Studies Depression (CES-D) scale, which was used to screen the participants for depressive symptomatology (Radloff, 1977). Then they took a 5-min break before completing the Montreal Cognitive Assessment (MOCA), a measure of general cognitive function (Nasreddine et al., 2005). The participants completed brief cognitive tasks until the 45-min delay had elapsed (e.g., Wisconsin Card Sorting Test, verbal fluency, and/or digit span). After the 45-min delay, participants were given as much time as they needed to describe, once again, as many of the pictures as they could remember from any of the four presentation blocks. The experimenter recorded their responses with an audio device. The entire session lasted up to 2 h. Participants received a written and oral debriefing at the end of the study.

### **Statistical Analyses**

The first author (K.T.A.B.) scored all of the recall data, and author L.F. double scored the data from 14 participants (i.e., 30%). Each picture description was considered a correct match if the rater could identify which picture was being described (without specific elements needing to be recalled). Correct matches were only given to pictures recalled in the correct study block (i.e., if a picture was recalled during a subsequent block, it would not count). We calculated the interrater reliability between the two raters using Pearson's correlations and Cohen's kappa.

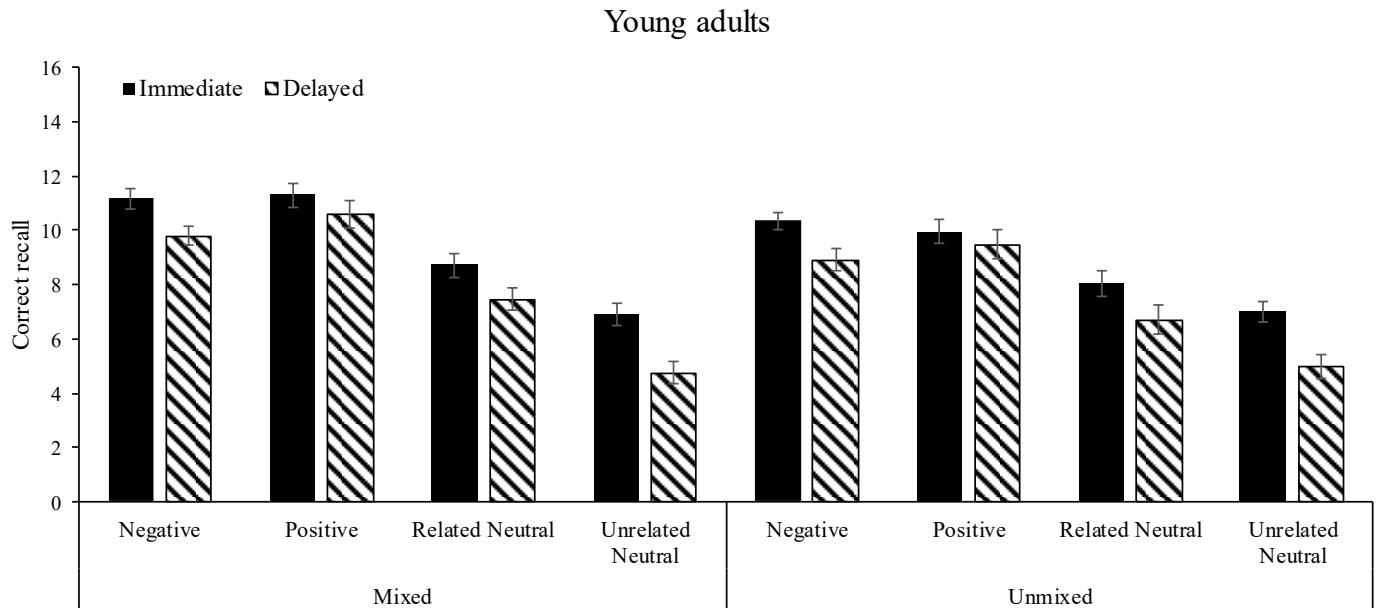
We then performed a 2 x 4 x 2 repeated measures ANOVA with distinctiveness (mixed, unmixed) as the between-subjects factor and picture type (negative, positive, related neutral, unrelated neutral) and recall delay (immediate, delayed) as within-subjects factors, on the number of correctly recalled pictures. Alpha was .05, and a Bonferroni-corrected alpha was used for post-hoc comparisons. Statistical analyses were performed using the SPSS Statistics 24 software.

### Results

The correlations between the two raters were high for all responses ( $r = .99$ ), picture types ( $r \geq .97$ ), and recall delays ( $r \geq .98$ ). Cohen's kappa also indicated high agreement for all responses ( $k = .95, p < .0001$ ), picture types ( $k \geq .90, p < .0001$ ), and recall delays ( $k \geq .94, p < .0001$ ). Fewer than 1% of descriptions were ambiguous and not matched to a target or buffer image.

The data were also normally distributed (based on kurtosis and skewness indices in SPSS), and there were no extreme outliers. The repeated measures ANOVA revealed main effects of picture type [ $F(3,135) = 77.60, p < .0001, \eta_p^2 = .63$ ] and recall delay [ $F(1,135) = 71.24, p < .0001, \eta_p^2 = .61$ ], as well as an interaction between picture type and recall delay [ $F(3,135) = 6.97, p < .0001, \eta_p^2 = .13$ ]. There was no main effect or interaction with distinctiveness (Figure 1). To examine the main effect of picture type, we calculated a total recall score summing the immediate and delayed totals for each participant. The paired  $t$ -tests revealed that participants recalled more positive and negative pictures than related-neutral and unrelated-neutral pictures ( $ps < .0001$ ), and more related-neutral pictures than unrelated-neutral pictures ( $ps < .0001$ ). No difference was found between the negative and positive pictures ( $p = .35$ ). Finally, the main

effect of recall delay resulted from higher recall at immediate testing ( $M = 36.74$  pictures,  $SD = 5.40$ ) than at delayed testing ( $M = 31.38$  pictures,  $SD = 6.23$ ).



*Figure 1.* Mean number of pictures correctly recalled by young adults after a 1-min (solid-coloured bars) and 45-min (striped bars) delay, based on picture type and study condition.

To examine the two-way interaction, we first compared the recall of each picture type for immediate and delayed tests separately, using paired  $t$ -tests (Bonferroni-corrected  $\alpha = .05/12 = .004$ ). The same pattern of results was found as above: At both test delays, participants recalled more positive and negative pictures than related-neutral and unrelated-neutral pictures ( $ps \leq .001$ ). They also recalled more related-neutral than unrelated-neutral pictures ( $ps \leq .001$ ), but there was no difference between positive and negative pictures (immediate,  $p = .690$ ; delayed,  $p = .064$ ). This did not explain the two-way interaction, so we performed additional exploratory

analyses comparing the immediate and delayed recall scores for each picture type separately, using paired *t*-tests (Bonferroni-corrected  $\alpha = .05/4 = .0125$ ). Recall was higher at immediate than at delayed testing for negative [ $t(46) = 5.93, p < .0001$ ], related-neutral [ $t(46) = 5.71, p < .0001$ ], and unrelated-neutral pictures [ $t(46) = 7.77, p < .0001$ ], but not for positive pictures [ $t(46) = 2.03, p = .05$ ]. The majority of pictures (92%) recalled in the delayed test were the same as those recalled in the immediate test; the numbers of novel pictures recalled during the delayed test were equal for each of the four picture types.

### Discussion

In Experiment 1 we assessed whether EEM in young adults results from the greater semantic interrelatedness and distinctiveness of the emotional stimuli. We compared the immediate and delayed recall of emotional pictures to two sets of neutral pictures (one high and one low in semantic interrelatedness) when the relative distinctiveness of the emotional stimuli was high (i.e., mixed condition) or low (i.e., unmixed condition).

Semantic relatedness contributed in part to EEM, but distinctive processing did not. The greater semantic relatedness of the related-neutral pictures improved recall relative to the unrelated-neutral pictures. This showed that without modifying the emotion of the pictures, increasing their semantic cohesion could itself improve both immediate and delayed recall (Buchanan et al., 2006; C. Hunt et al., 2015; Talmi & Moscovitch, 2004). Contrary to our predictions (Schmidt & Saari, 2007; Talmi & McGarry, 2012), distinctive processing did not influence EEM. Recall was greater for the emotional than for the related-neutral items when distinctive processing was uncontrolled in the mixed condition, but also when it was controlled in the unmixed condition. Although the EEM pattern was observed at both recall delays, we observed an unexpected interaction with picture type. Whereas most pictures (i.e., negative,

related neutral, unrelated neutral) were recalled better in the immediate than in the delayed test, positive pictures maintained a stable rate of recall after the delay. This suggests that positive pictures were ‘forgotten’ at a slower rate than the other pictures. Although there was no relative difference in recall for positive and negative pictures at either immediate or delayed testing, the decelerated forgetting of positive pictures could be interpreted as a positivity advantage that appeared over time. This was contrary to our prediction that young adults would show a negative memory bias.

In the following experiment, we sought to reexamine the roles of semantic relatedness and distinctive processing on young adults’ EEM, this time also including older adults. Using the same methods and design, we wanted specifically to examine the positive memory biases of older adults and how they compare to the emotional biases of young adults.

## Experiment 2

In Experiment 2, we recruited French young and older adults to complete the same emotional memory paradigm used in Experiment 1 (Talmi, Luk, et al., 2007). The main focus of this study was to determine whether semantic relatedness and distinctiveness account for EEM in young and older adults (Talmi & McGarry, 2012). More specifically, we expected distinctive processing to underlie older adults’ positive memory bias.

## Method

### Participants

In Experiment 2, we aimed to test 60 young adults and 60 older adults in order to obtain power of .90 for the within-between interaction (determined a priori using the G\*Power

software; Faul, Erdfelder, Buchner, & Lang, 2009). The final sample included 61 young adults (under 35 years old) and 59 older adults (over 60 years old; see Table 4), randomly assigned to the mixed or unmixed condition. The young adults attended the University of Grenoble or the University of Savoie Mont Blanc, and they received course credit for participating. The older adults resided in Grenoble, Chambéry, or Lyon, and they received no compensation. Participants provided their written informed consent and completed the study in French. This study was approved by the University of Ottawa (#H12-14-14) and University of Savoie Mont Blanc (#20158) Research Ethics Boards.

Table 4

*Demographic Information for the Young and Older Adults in Experiment 2*

	Young		Older	
	Mixed	Unmixed	Mixed	Unmixed
<i>n</i>	31 (7 men)	30 (5 men)	28 (7 men)	31 (9 men)
Age	20.32 (2.06)	20.30 (3.96)	74.75 (6.38)	74.10 (5.31)
Education	13.42 (1.21)	13.03 (1.38)	12.43 (2.69)	12.13 (2.75)
MOCA	27.42 (1.57)	27.37 (1.88)	26.68 (1.85)	26.00 (2.24)
FAB	17.29 (0.82)	17.17 (0.95)	16.52 (1.08)	16.81 (0.91)
CES-D	13.19 (9.05)	14.53 (9.46)	7.78 (5.04)	11.39 (8.10)

*Note.* Mean and SD for age (in years), education (in years), Montreal Cognitive Assessment (MOCA), Frontal Assessment Battery (FAB), and Centre for Epidemiologic Studies Depression scale (CES-D)

Participants reported that they were in good health, with no psychiatric or neurological condition. They were further screened for possible cognitive impairment using the Montreal Cognitive Assessment (MOCA; Nasreddine et al., 2005) and the Frontal Assessment Battery (FAB; Dubois, Slachevsky, Litvan, & Pillon, 2000), and for depressive symptomatology using

the CES-D (Radloff, 1977). Five young adults were excluded because of experimenter error ( $n = 2$ ), age (53 years old), extreme CES-D score ( $z$  score = 3.62), and outlying delayed-recall scores (kurtosis = 2.68; this participant did not understand the delayed recall instructions). Three older adults were excluded because of an incomplete study session, a low MOCA score of 18 ( $z$  score = -3.82), and low MOCA (17) and FAB (10) scores ( $z$  scores of -4.26 and -5.81, respectively). The young adults in both conditions were matched in their age, education, MOCA, FAB, and CES-D. The older adults were matched in age, education, MOCA, and FAB, although those assigned to the unmixed condition may have had greater depressive symptomatology (i.e., higher CES-D scores) than those assigned to the mixed condition [ $t(56) = 2.00, p = .050$ ]. The CES-D scores were therefore inputted as a covariate, to control for this difference at baseline.

### **Stimuli**

Experiment 2 included the same number of pictures (64 targets and 16 buffers) and the same picture categories (negative, positive, related neutral, unrelated neutral) as Experiment 1. Most of the same pictures were used, except for one unrelated-neutral, two related-neutral, two positive, and seven negative pictures.

Ratings of valence, arousal, and semantic interrelatedness (Table 3) were obtained from 13 students from the University of Savoie Mont Blanc and 14 older adults (62-83 years old) from the wider community. The students completed the ratings as per the procedures described in Experiment 1. The older adults completed the study online and saw only a portion of all trials, to ensure that the study lasted less than 1h. By-item univariate ANOVAs conducted separately for the young and older adults showed that the four picture types differed significantly in valence [young,  $F(3,60) = 280, p < .0001$ ; older,  $F(3,60) = 157, p < .0001$ ], arousal [young,  $F(3,60) = 94, p < .0001$ ; older,  $F(3,60) = 24, p < .0001$ ], and semantic relatedness [young:  $F(3,60) = 84, p <$

.0001; older:  $F(3,60) = 65, p < .0001$ ]. Planned contrasts with Bonferroni correction showed that all pictures differed in valence ( $ps < .0001$ ), except for the two neutral categories ( $p > .999$ ).

Young adults rated the emotional pictures as being more arousing than the neutral pictures ( $ps < .0001$ ), but they did not rate the negative and positive pictures differently ( $p = .110$ ), nor did they rate the related-neutral and unrelated-neutral pictures differently ( $p = .237$ ). In contrast, older adults rated the negative pictures as being more arousing than the rest ( $ps < .0001$ ) and reported no differences in arousal between positive, related-neutral, and unrelated-neutral pictures ( $ps > .999$ ). Importantly, for both age groups the negative, positive, and related-neutral pictures were more highly interrelated than the unrelated-neutral pictures ( $ps < .0001$ ). Young adults rated the related-neutral pictures as being more interrelated than the negative ( $p = .038$ ) and positive ( $p < .0001$ ) pictures, but they rated the positive and negative pictures equally ( $p = .922$ ). In contrast, older adults rated the negative pictures as being more interrelated than positive ( $p = .011$ ) and related-neutral ( $p = .044$ ) pictures, which they rated as being equally interrelated ( $p > .999$ ).

## **Procedures**

The procedures were identical to those of Experiment 1, except that the Frontal Assessment Battery replaced the Wisconsin Card Sorting Test in Experiment 2.

## **Statistical Analyses**

The primary rater (K.T.A.B.) scored all of the recall data, and the secondary rater (nonauthor K.I.N.) double scored nearly 25% of the data (immediate recall from 15 young and 15 older adults, and delayed recall from 12 young and 15 older adults). The secondary rater in this experiment was completely blind to the research hypotheses and did not test any of the participants. The picture descriptions were scored in accordance with the rules outlined in

Experiment 1. The inter-rater reliability between the primary and secondary raters was calculated with Pearson's correlations and Cohen's kappa indices.

We performed a 2 x 2 x 4 x 2 repeated measures ANOVA with Age (young, older) and distinctiveness (mixed, unmixed) as between-subjects factors, and picture type (negative, positive, related neutral, unrelated neutral) and recall delay (immediate, delayed) as within-subjects factors, on the total number of correctly recalled pictures. CES-D scores were included as a covariate because of the older adults' difference at baseline<sup>6</sup>. Alpha was set to .05. Given the large number of post-hoc comparisons, we used a Holm–Bonferroni correction (Holm, 1979), which is a sequentially rejective procedure useful for performing multiple contrasts without increasing Type I error. The rank order (from smallest to largest) is reported for each  $p$  value. Statistical analyses were performed using the SPSS Statistics 24 software.

## Results

### Interrater Reliability and Assumptions

The correlations between the two raters were high for all responses ( $r = .99$ ), and equally high for the two age groups ( $r \geq .98$ ), four picture types ( $r \geq .96$ ), and two recall delays ( $r \geq .98$ ). Cohen's kappa also indicated high agreement for all responses ( $k = .92, p < .0001$ ), age groups ( $k \geq .89, p < .0001$ ), picture types ( $k \geq .90, p < .0001$ ), and recall delays ( $k \geq .90, p < .0001$ ). Approximately 1.55% of descriptions were ambiguous and could not be matched to an image, which occurred more frequently for older than for young adults [older adult,  $M = 1.07$  ambiguities; young adult,  $M = 0.44$  ambiguities;  $t(118) = 3.38, p = .001$ ]. We excluded one young-adult outlier that was negatively skewing the delayed recall of positive pictures (kurtosis

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<sup>6</sup> One older adult did not complete the CES-D and was therefore removed from the ANOVA, but this participant was included in the post-hoc comparisons that did not involve CES-D score.

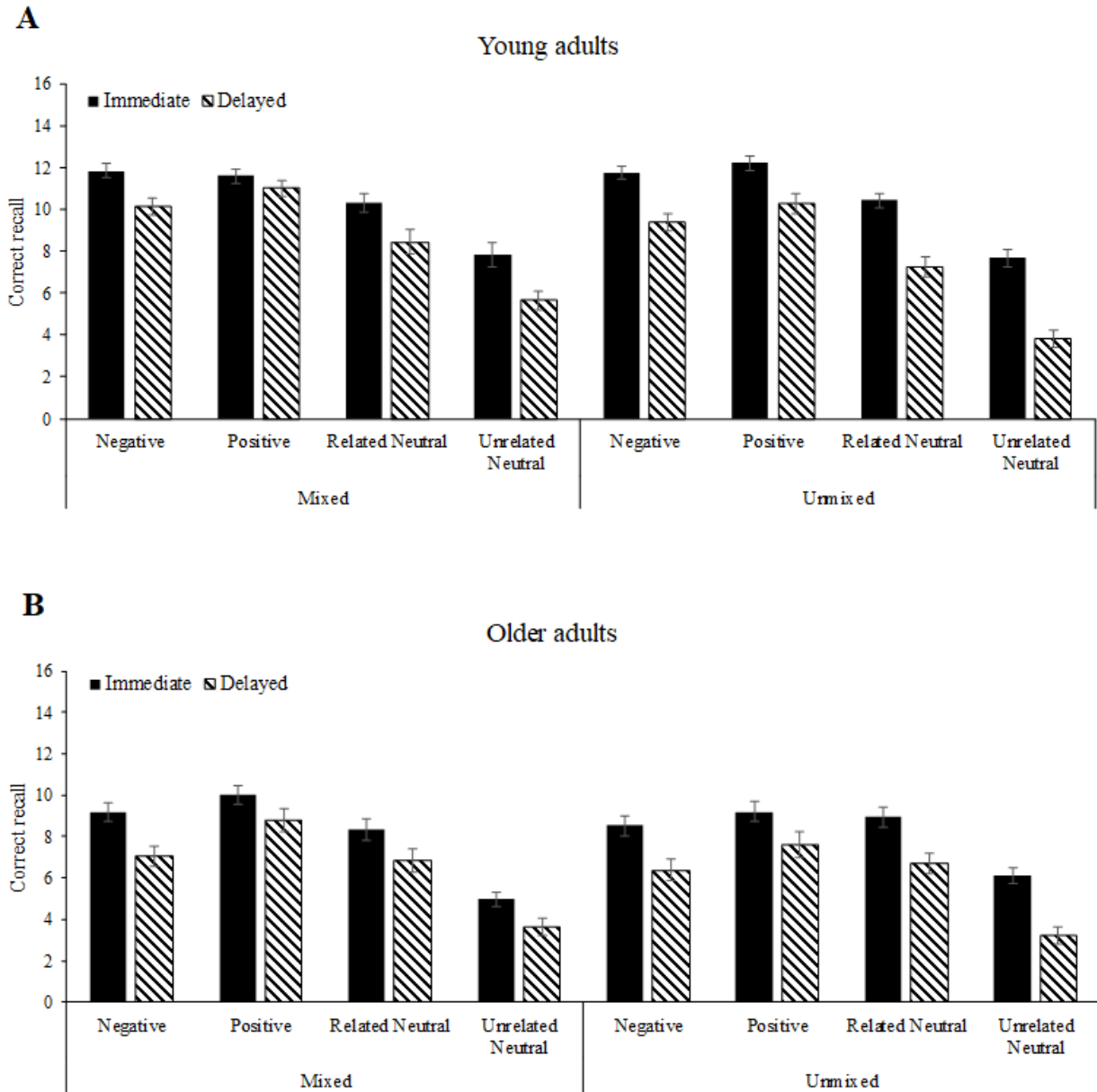
= 2.68; skewness = -1.03). This participant did not understand the delayed-recall instructions and only recalled pictures from one picture category. After excluding this participant, the data were normally distributed.

### Repeated ANOVA and Post-Hoc Tests

We used a Huynh-Feldt correction because of a violation of sphericity. The repeated measures ANOVA revealed main effects of age [ $F(1,114) = 41.69, p < .0001, \eta_p^2 = .268$ ], picture type [ $F(3,342) = 52.12, p < .0001, \eta_p^2 = .314$ ], and recall delay [ $F(1,114) = 77.04, p < .001, \eta_p^2 = .403$ ], but no main effect of distinctiveness ( $p = .255$ ; Figure 2). These findings were characterized by the following interactions: Distinctiveness x Age x Picture Type [ $F(3,342) = 3.19, p = .024, \eta_p^2 = .027$ ], Age x Picture Type [ $F(3,342) = 3.75, p = .011, \eta_p^2 = .032$ ], Distinctiveness x Recall Delay [ $F(1,114) = 11.84, p = .001, \eta_p^2 = .094$ ], and Recall Delay x Picture Type [ $F(2.91,332) = 3.07, p = .029, \eta_p^2 = .026$ ]. The CES-D covariate did not significantly affect these results.

To further examine the three-way interaction, we calculated the total recall for each picture type summed across recall delays. We performed a series of paired *t*-tests contrasting the levels of picture type (i.e., negative vs. positive, negative vs. related neutral, etc.) for each Age and distinctiveness condition separately. Young adults' EEM was consistent in both the mixed and unmixed conditions: They recalled more positive and negative pictures than related-neutral pictures ( $ps < .0001$ ), and more related-neutral than unrelated-neutral pictures ( $ps < .0001$ ), with no difference between the positive and negative pictures. EEM was therefore always present in young adults with no emotional bias toward either negative or positive pictures. In contrast, the

older adults in the mixed condition remembered more pictures from the positive category than from any other category, showing evidence of a positivity bias [positive vs. negative,  $t(27) =$



*Figure 2.* Mean number of pictures correctly recalled by young adults (A) and older adults (B) after a 1-min (solid-coloured bars) and 45-min (striped bars) delay, based on picture type and study condition.

3.24, 18<sup>th</sup> ranked  $p = .003$ ; positive vs. related-neutral,  $t(27) = 4.70, p < .0001$ ; positive vs. unrelated neutral,  $t(27) = 11.04, p < .0001$ ]. Older adults' positivity bias disappeared in the unmixed condition: They recalled equal amounts of positive, negative, and related-neutral pictures [positive vs. negative,  $t(30) = 2.54, 19^{\text{th}}$  ranked  $p = .017$ ; positive vs. related neutral,  $t(30) = 1.37, 21^{\text{st}}$  ranked  $p = .181$ ; negative vs. related neutral,  $t(30) = 0.91, 23^{\text{rd}}$  ranked  $p = .373$ ]. In both distinctiveness conditions, young as well as older adults always recalled fewer unrelated-neutral pictures than all other types of pictures ( $ps < .0001$ ), thus demonstrating the classic EEM effect.

The two-way interaction between age and picture type therefore resulted from a positivity bias that was present in older but not in young adults. Another interaction existed between distinctiveness and recall delay: Participants' total recall on the delayed test (summed across all picture types) was higher in the mixed than in the unmixed condition [ $t(118) = 2.30, 1^{\text{st}}$  ranked  $p = .023$ ]. Recall delay also interacted with picture type: The memory advantage for positive over negative pictures was significant for the delayed test [ $t(119) = 5.10, p < .0001$ ] but not for the immediate test [ $t(119) = 1.92, 12^{\text{th}}$  ranked  $p = .057$ ]. We observed no differential rate of forgetting: All pictures were recalled better on the immediate than on the delayed test [ $ps < .0001$  for all picture types]. We further explored this interaction by examining the number of novel pictures recalled during the delayed test that were not recalled during the immediate test (8% of the total delayed recall). Indeed, more novel pictures were recalled from the positive category than from the negative [ $t(31) = 3.82, p = .001$ ] or unrelated-neutral [ $t(31) = 3.69, p = .001$ ] categories.

## Discussion

Using the same methods and procedures as in Experiment 1, we assessed whether semantic relatedness and distinctiveness explain EEM in young adults, and more specifically the positivity bias in older adults. We compared immediate and delayed free recall of negative, positive, related-neutral, and unrelated-neutral pictures when the relative distinctiveness of emotional stimuli was high (i.e., mixed condition) or low (i.e., unmixed condition).

In this experiment, older adults recalled more positive than negative or neutral pictures when these items were processed in a distinctive manner. But this ‘positivity effect’ disappeared when both distinctive processing and semantic interrelatedness were controlled in the unmixed condition. On the other hand, young adults showed no emotional bias toward either positive or negative pictures, and their recall was not influenced by distinctiveness, although higher semantic interrelatedness enhanced memory for neutral pictures. The classic EEM effect was observed in all conditions and age groups when comparing the recall of emotional pictures to that of unrelated-neutral pictures.

## General Discussion

In healthy older adults, positive information seems easier to remember than negative information, even when it is retrieved after a short delay. But does this age-related positive memory bias result from an absolute memory decrease for negative information, or simply from a contextual advantage that appears when positive information is processed in relation to negative information? The findings of this study support the latter possibility: Older adults remembered more positive than negative pictures when studying them together, at the same time (i.e., mixed condition), but not when studying/recalling them separately (i.e., unmixed condition). The study context did not affect young adults, who consistently recalled equal

proportions of positive and negative pictures. Enhanced emotional memory in young and older adults was further attributed to the higher semantic relatedness of the emotional pictures. These findings were consistent across 1-min and 45-min test delays.

### **Semantic Relatedness**

The present experiments build on previous work (Talmi & McGarry, 2012) that had identified semantic relatedness and distinctive processing as two cognitive factors underlying emotion-enhanced memory in young adults (when tested shortly after study; i.e., early EEM). In the present study, neutral pictures were either (a) low in semantic relatedness (i.e., they were selected randomly) or (b) high in semantic relatedness (i.e., they were selected according to a general theme), at levels comparable to the emotional pictures. Young and older adults consistently remembered more items from the related-neutral than from the unrelated-neutral category, demonstrating that increased organization improved memory for the neutral items. This extends previous findings with young adults (Buchanan et al., 2006; Talmi, Luk, et al., 2007; Talmi, Schimmack, et al., 2007) by showing that older adults' memory also improves when the stimuli are more interrelated. This is in line with reports of older adults utilizing pre-existing associations between study items to improve their associative memory (Naveh-Benjamin et al., 2005; Naveh-Benjamin et al., 2003). Here, no active elaboration was required during study, because the related-neutral stimuli were already organized around a common theme (i.e., the house), so older adults' memory could likely improve without their needing to exert additional cognitive resources ( Craik, 1983, 1986).

Importantly, when controlling distinctive processing (i.e., an unmixed condition), older adults only demonstrated EEM when the emotional items were more interrelated than the neutral items (i.e., positive/negative vs. unrelated-neutral), but not when the neutral items were also more

closely interrelated (i.e., positive/negative vs. related-neutral), suggesting that older adults' EEM depended in part on semantic relatedness. Furthermore, in the unmixed condition, older adults did not show a positivity bias, perhaps because the high interrelatedness of negative pictures facilitated their encoding and/or retrieval when processed separately from the positive pictures. The large variability across existing findings on the positivity effect thus might result in part from the uncontrolled effects of semantic relatedness. Future work should carefully consider item interrelatedness and its effects on EEM and the positivity effect in aging.

### **Distinctiveness**

In the present experiments, participants processed emotional pictures in either a relatively distinct manner (mixed condition), by studying emotional and neutral pictures at the same time, or in a nondistinctive manner (unmixed condition), by studying and recalling each picture category separately. Relative distinctiveness influenced memory in older but not in young adults. Older adults showed a positive memory bias when positive pictures were relatively distinct in the mixed condition, but they recalled equal numbers of positive, negative, and related-neutral pictures when distinctive processing was minimized in the unmixed condition. This is in line with previous reports that have failed to show a positivity bias when using unmixed study designs (Emery & Hess, 2011; Grühn et al., 2007; Grühn et al., 2005). To our knowledge, this is the first study to have shown that older adults' positivity bias selectively appeared when positive stimuli were relatively distinct as compared to the negative and neutral stimuli, while also controlling item interrelatedness.

Previous reports on the positivity effect in aging may have overestimated the size and/or robustness of the effect by using predominantly mixed (vs. unmixed) study designs that enhance older adults' processing of positive stimuli. The present findings suggest that older adults can

recall positive and negative information equally well, provided that the two information types are studied independently. In other words, older adults' memory for negative stimuli might simply decrease when it competes for resources with positive stimuli. This is particularly relevant for older (but not younger) adults because of the perceptual and cognitive reductions common in normal aging (e.g., poorer vision, slower processing speed, reduced attention). Given these limitations, older adults might be unable to successfully attend to and memorize all stimuli; therefore, some stimuli will be favored over others. Positive stimuli may be prioritized for a number of reasons. First, positive information helps older adults fulfill their current goals of life satisfaction and emotional well-being (the socioemotional selectivity theory; Carstensen et al., 1999; Charles et al., 2003). Second, positive information may be less complex (visually and/or semantically) than negative information, rendering it easier to process (Labouvie-Vief, 2003; Labouvie-Vief et al., 2010). Third, alterations in fronto-amygdalar brain activity may selectively reduce the perceptual processing of negative stimuli and increase emotion regulation, which can facilitate the processing of positive over negative stimuli (Leclerc & Kensinger, 2010, 2011; Mather et al., 2004; St. Jacques, Dolcos, & Cabeza, 2010). For these reasons, among others, positive stimuli may be easier to remember than negative stimuli when both types are processed at the same time. In real life, older adults certainly might experience a mix of positive and negative events close in time, or a single event could even elicit mixed emotions<sup>7</sup>. In these cases, older adults would tend to remember the positive events better than the rest. This would explain why the positivity bias is frequently observed in real life, because positive events are often processed relative to other events. Nonetheless, the results of the present study suggest that older

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<sup>7</sup> We thank a reviewer for this remark.

adults would still maintain the ability to remember negative events well, provided the events are experienced in isolation from other emotional events.

Contrary to the older adults in our study, the young adults' EEM was not influenced by distinctiveness. In both experiments, young adults recalled more positive and negative pictures than related-neutral or unrelated-neutral pictures. This is contrary to previous findings, in which young adults remembered equal numbers of negative and neutral words (Dewhurst & Parry, 2000; Hadley & MacKay, 2006; Schmidt & Saari, 2007) and pictures (Talmi, Luk, et al., 2007; Talmi & McGarry, 2012) when studying each category individually. The purpose of controlling distinctiveness is to minimize the processing advantage of emotional relative to neutral information. Yet, even when stimuli are processed in isolation from one another, emotional stimuli might still engage more attention than neutral stimuli, perhaps due to their high salience, goal relevance, or ability to induce arousal (Barnacle, Montaldi, Talmi, & Sommer, 2016; Murphy & Isaacowitz, 2008; Pourtois, Schettino, & Vuilleumier, 2013; Vuilleumier, 2005). Therefore, many factors beyond relative distinctiveness might lead emotional stimuli to capture more attention than neutral stimuli. According to Mediation Theory (Talmi, 2013; Talmi & McGarry, 2012; Talmi et al., 2013), increased attention, semantic relatedness, and distinctiveness, can fully account for the immediate emotional enhancement of memory. In the present experiments, we attempted to reduce potential differences in attention allocation by using full-attention, intentional-encoding instructions with slow presentation times, but there was no direct measure of attention. It is possible that some uncontrolled characteristic in the pictures (e.g., arousal or visual complexity) led the emotional ones to capture more attention than the neutral ones, regardless of the distinctiveness condition. In future work, it will be necessary to

measure and/or manipulate attention directly, to determine the extent to which distinctive processing alters attention allocation and subsequent EEM effects.

### **Test Delay**

A final consideration was whether testing memory 1 min or 45 min after study would influence the effects of relatedness and distinctiveness. Overall, memory was greater the sooner it was tested. In Experiment 1, EEM in young adults was present at both delays. Exploratory analyses suggested that young adults forgot positive pictures at a slower rate than all the other pictures, but this was not replicated in Experiment 2. Nonetheless, this differential forgetting rate for positive pictures in young adults is surprising given our expectation that they would prioritize negative information. In Experiment 2, the test delay directly affected EEM: Participants recalled more positive than negative pictures when tested after 45 min but not when tested after 1 min, perhaps due to participants' remembering novel positive pictures during the delayed testing that they had forgotten during the immediate testing. This result did not further interact with age, although it was likely driven by the positivity bias in older adults. This may suggest that older adults' positivity bias becomes stronger over time, similar to young adults' EEM becoming stronger over time (Yonelinas & Ritchey, 2015). A between-subjects design testing recall at two or more delays would be useful to disentangle the effects of repeated testing from those of delayed testing.

### **Conclusion**

When examining the aging positivity effect, it is important to consider basic cognitive factors that can improve encoding and/or retrieval. Semantic relatedness partly explained EEM in young adults, and relatedness together with distinctiveness entirely explained memory in older adults. Distinctive processing was necessary for producing older adults' positivity bias, which

disappeared when distinctiveness was controlled. This argues that the positivity effect reflects a temporary contextual advantage for positive information that can be eliminated by controlling item interrelatedness and distinctiveness.

The present findings are consistent with the few previous aging studies that have used unmixed study designs (Emery & Hess, 2011) or have directly contrasted unmixed and mixed sets (Grühn et al., 2007; Grühn et al., 2005), all of which failed to find a positivity bias in aging memory. On the one hand, this might have been due to specific stimulus characteristics (Grühn et al., 2005) or memory assessment procedures (Grühn et al., 2007) that might have attenuated the positivity effect in aging (Reed et al., 2014). On the other hand, it might be that the majority of previous reports, which have used mixed designs and paid little attention to item interrelatedness, have overestimated the size and/or robustness of the aging positivity effect. Note that we do not claim here that this effect does not exist. However, we would urge care moving forward in studying the aging positivity effect. Item interrelatedness and distinctiveness are but two cognitive factors that can influence emotion-enhanced memory, and they should be accounted for carefully in future work.

### **Author Note**

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**Study 2A. Mood Induction Using Online Videos**

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### Abstract

Emotion-eliciting films have been invaluable to studying the effects of emotion and mood on cognition. However, the film clips available in previous databases were often selected from well-known movies (e.g., *Bambi* or *When Harry Met Sally*), which may be highly familiar to participants and lack realism. In the current study, we compiled a set of 29 video clips (11 positive, 8 negative, 10 neutral) from online sources to minimize participant familiarity. The videos varied in duration (mean = 3:40 min; range = 30 s to 5:43 min). Thirty-two men and 46 women (mean age = 20.29 years) viewed a subset of the videos and rated their emotional valence and arousal on a 9-point scale (P. J. Lang et al., 2008), and indicated whether they had previously seen the clip. Each video was rated by a minimum of 30 participants. Paired *t*-tests confirmed that the three types of videos elicited differences in emotional valence. The positive and negative videos elicited equally high levels of arousal. The videos were mostly unfamiliar, with the exception of a few positive clips. These videos contribute to the ever-growing affective film libraries.

*Keywords:* emotion, films, valence, arousal, familiarity, validation

## Introduction

Mood influences our everyday thoughts and behaviours. Even the slightest change can greatly influence brain activity and cognition (Mitchell & Phillips, 2007). To reliably study these effects, researchers can experimentally manipulate participants' mood prior to or during a task, thereby exerting maximum experimental control. But positive and negative moods seem to engage different neurotransmitter systems in the brain, each exerting their unique influences on behaviour (Mitchell & Phillips, 2007). A valid mood induction protocol must therefore include realistic and immersive stimuli that are equally effective at altering mood in either direction.

Experimentally inducing moods is more powerful than obtaining self-rated mood because it tests for a causal, rather than merely correlational, relationship between mood and behaviour. Moreover, induced moods appear to recruit similar brain networks as naturalistic moods (Mayberg et al., 1999). Perhaps the most common and effective mood induction technique is the presentation of short affective films or video clips (Robinson, Grillon, & Sahakian, 2012; Westermann et al., 1996). Affective films can readily capture attention and elicit intense, long-lasting emotions (Rottenberg et al., 2007). In addition, they are easy to use and minimize the amount of experimenter-participant interaction, allowing for a standardized procedure across participants and laboratories (Robinson et al., 2012).

To date, several affective film libraries exist (see Gilman et al., 2017), yet these commonly include scenes from well-known movies (e.g., *Bambi* or *When Harry Met Sally*), which present a number of limitations. First, participants' previous exposure to these movies may alter their attention (Hutchinson & Turk-Browne, 2012; Kuhl & Chun, 2014) and emotional responses (Gabert-Quillen, Bartolini, Abravanel, & Sanislow, 2015). Second, movies may be heavily edited and scripted, thus reducing their affective realism (Samson, Kreibig, Soderstrom,

Wade, & Gross, 2016). This may be especially true of older movies that appear outdated. These factors may reduce the effectiveness of using movies in mood induction protocols. As an alternative, researchers may use amateur videos from online sources because these depict real-life events and may elicit more naturalistic emotional responses than movie clips (Samson et al., 2016).

A final consideration is the matching in emotional intensity of positive and negative moods. In general, positive moods are more challenging to elicit than negative moods (Westermann et al., 1996). There may simply exist more variability in what makes people happy than in what makes people unhappy. But positive and negative moods should be matched in their arousal (i.e., intensity) because of arousal's vast effects on perception and memory (Ack Baraly et al., 2017; Mather & Sutherland, 2011). Positive and negative emotional responses may also be differentially influenced by participant familiarity. When participants have seen a video before, they may respond more strongly when it is a positive video and less strongly when it is a negative video (Gabert-Quillen et al., 2015). Inducing a negative state may therefore be more challenging when using familiar content. For these reasons, it is important to select positive and negative mood induction videos that are equally intense and novel.

The aim of the current study was to select unfamiliar videos from online sources that could induce equally strong positive and negative moods in participants. We selected mostly amateur videos (similar to Samson et al., 2016) and included a few animated films for further options. The current set of videos are longer (mean duration = 3:40 min) than those available in other online video databases (e.g., Samson et al., 2016). This was to facilitate including physiological measurements in future work (e.g., electrocardiography). We provide ratings of familiarity, valence, and arousal for a total of 29 video clips.

## Methods

### Participants

Eighty-one students were recruited from the University of Ottawa and compensated with course credit. Three participants were excluded: Two were sleeping and/or not paying attention to the videos, and another was an outlier with a neutral response bias. The final sample included 78 students (32 men; mean age = 20.29 years  $\pm$  2.33 *SD*). All participants provided their written informed consent. The study was approved by the University of Ottawa's Research Ethics Board (#H12-14-14).

### Videos

All videos were downloaded from online sources (YouTube and Vimeo) using DVDFab 9 software. We selected the highest available resolution and maintained the original frame speed. All clips included their original audio (instrumental music or English dialogue) and were in .avi format (codec: H.264). We used Filmora software to shorten or combine some videos to obtain the final set of 29 clips (11 positive, 8 negative, and 10 neutral, as categorized by two researchers). Most videos depicted real-life scenes of humans and/or animals, but two positive and two negative videos were selected from animated short films. The clips varied in duration (mean = 3:40 min; range = 30 s to 5:43 min). Video details including title, description, duration, target mood, and online URL are found in Appendix A.

### Procedures

At the start of the experiment, participants completed the written informed consent and a demographics form. Participants completed the ratings task in a separate room from the experimenter and were monitored by video camera throughout the session. During the study, participants viewed the video clips one at a time, in pseudo-random order, and listened to the

audio through headphones. After each video clip, participants rated their valence and arousal using the Self-Assessment Manikins (P. J. Lang et al., 2008). Valence was rated from 1 (happy) to 9 (unhappy), and arousal from 1 (excited) to 9 (calm)<sup>8</sup>. Participants also indicated whether they had seen the video clip prior to the experiment (*yes* or *no*). Participants were given the option to take a break between videos or to skip a video, as needed. When a video was skipped, the participant's ratings for that video were removed but all other ratings were retained. Participants viewed only a subset of the videos (up to 10 maximum), to limit the possible effects of fatigue and carry-over from one video to the next. The session lasted up to one hour. Upon completion, participants were debriefed and care was taken to minimize any adverse effects of viewing the videos.

## Results

### Familiarity

The negative and neutral videos were unfamiliar. On average, fewer than 1% of participants had previously seen them prior to the study (range 0% to 3%, see Table 5). The positive videos were more familiar; an average of 18% of participants had seen them before the experiment (range 0% to 43%). A visual inspection of the data shows that in general, as participant familiarity with the positive videos increased, so did their level of self-reported valence and arousal<sup>9</sup>.

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<sup>8</sup> This is contrary to P. J. Lang et al. (2008) who scored arousal from 9 (excited) to 1 (calm). We chose to invert the numbers to maintain the spatial coherence between the keyboard (1 to 9) and the Self-Assessment Manikin which goes from excited (left) to calm (right).

<sup>9</sup> No correlations were calculated between familiarity and valence/arousal because 1) the data are too skewed to obtain a meaningful statistic when including the negative and neutral videos; 2) there are too few positive videos ( $n = 11$ ) to run the correlations separately.

Table 5

*Self-Report Ratings for All Video Clips*

Video clip	N	Valence		Arousal		Familiarity (%)
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
<b>Positive</b>						
Dogs and stairs 1	36	1.97	1.18	3.53	1.89	19.4
Babies laughing 1†	34	2.03	1.13	4.03	2.30	26.5
Babies laughing 2	40	2.05	1.38	3.40	1.93	42.5
Dogs and stairs 2†	37	2.38	1.44	4.57	2.61	5.4
Presto	36	2.50	1.36	3.86	2.00	8.3
Babies and dogs	35	2.57	1.09	4.80	2.18	0
Baby dancing	34	2.76	1.18	4.71	1.98	23.5
Partly Cloudy	33	2.91	1.89	4.30	2.08	21.2
Child scared of monsters	36	3.06	1.43	5.44	2.10	22.2
Baby saying no	34	3.41	1.31	5.35	2.19	8.8
Baby with hiccups	32	3.72	1.73	5.41	2.21	3.1
<b>Neutral</b>						
Beaver	34	3.44	1.78	7.15	2.00	0
Turtle	35	4.06	1.54	6.18	2.55	2.9
Ducks	36	4.42	1.13	7.64	2.10	0
Dog competition	36	4.50	1.46	6.75	2.41	0
Interview	36	4.50	1.11	5.33	2.23	0
Fish	36	4.67	1.22	5.56	2.48	2.8
Library tour†	35	5.00	1.31	7.51	2.06	0
Dali museum tour	32	5.28	1.46	8.31	1.23	0
Hannah and her sisters	37	5.32	1.00	6.73	1.87	2.7
Van Gogh tour†	32	5.53	1.59	7.90	1.56	0
<b>Negative</b>						
StoryCorps 1	31	6.23	2.55	4.78	2.64	3.2
StoryCorps 2	37	6.84	1.83	5.43	2.12	0
Children with cancer	35	7.03	1.36	5.89	1.84	0
Dog with lesions	39	7.30	1.71	5.37	2.08	0
Huntington's disease 1	34	7.47	1.19	5.47	2.33	0
Dog eye surgery†	37	7.58	1.83	5.06	2.46	0
Huntington's disease 2†	37	7.73	1.45	5.49	2.05	0
Child with leukemia	37	7.78	1.20	5.46	2.16	0

*Note.* Valence was rated from 1 (happy) to 9 (unhappy), and arousal from 1 (excited) to 9 (calm). Familiarity refers to the percentage of participants who indicated having seen the video prior to the experiment. †Videos we selected for our future work.

## Valence and Arousal

We performed a MANOVA with Video Type (positive, negative, neutral) as a between-item variable and valence and arousal ratings as the dependent variables. There was a significant main effect of Video Type for both valence [ $F(2,28) = 192.43, p < .001, \eta_p^2 = .912$ ] and arousal ratings [ $F(2,28) = 34.59, p < .001, \eta_p^2 = .712$ ]. Independent *t*-tests confirmed that the positive, negative, and neutral videos each induced different levels of emotional valence ( $ps < .001$ ), in the directions expected (i.e., participants felt pleasant after viewing the positive videos, unpleasant after viewing the negative videos, and neutral after viewing the neutral videos). Each of the negative videos differed in valence from the positive videos (range: 6.23-7.78 vs. 1.97-3.72, respectively), but there was some overlap in valence between the positive and neutral videos (range: 1.97-3.72 vs. 3.44-5.53, respectively). Crucially, the positive and negative videos induced equal levels of arousal ( $p = .307$ ) and were more arousing than the neutral videos ( $ps < .001$ ). Most neutral videos were low arousal (range: 5.33-8.31, where 1 is high arousal and 9 is low arousal). The negative and positive videos were higher in arousal, with the latter having a larger range of scores (4.78-5.89 vs. 3.40-5.44, respectively).

## Discussion

Researchers continue to develop affective film libraries to study the various effects of mood on cognition, in part because older films might become obsolete. The purpose of the current experiment was to select unfamiliar video clips from online sources that would be equally effective for inducing positive and negative moods. The clips elicited a range of positive, negative, and neutral emotional responses. Most importantly, the positive and negative videos appeared to be equally arousing for participants, despite the positive videos being somewhat

more familiar. These videos complement existing film libraries by diversifying the range of affective tools available to researchers.

### **Familiarity**

In the current set of videos, the positive clips were more familiar to participants than the negative and neutral clips. Our goal was to include mostly unfamiliar videos so that participants' prior exposure to them would not influence their processing and emotional responses. However, this was not the case, because some of the positive clips were previously seen by up to 40% of participants. This is likely due to the present viral nature of positive online videos. Although it is ideal to use unfamiliar stimuli in an experiment, familiarity did not seem to lessen participants' emotional responses and might have even increased their positivity and arousal. As a general precaution, researchers should ask participants about their familiarity with experimental videos subsequent to any manipulation.

### **Positive vs. Negative Emotions**

As expected, the positive and negative videos induced different levels of emotional valence than the neutral videos. Most importantly, the positive videos were just as arousing as the negative videos, both of which were more arousing than the neutral videos. A general concern is that positive videos are harder to induce and may be less arousing than negative videos (Westermann et al., 1996). In the current set, all emotional videos were medium to high arousal, and the positive videos had an even higher range of arousal scores than the negative videos. This could have partially resulted from participants' increased familiarity with some of the positive videos (Gabert-Quillen et al., 2015).

## **Applications**

Based on the ratings collected here, we have identified two videos per category (see Table 5) that we would recommend for use in future studies. We suggest using two videos per mood induction category, so that findings are more generalizable beyond a single video. Researchers are encouraged to collect ratings of valence and arousal to validate the videos locally, and should also obtain information as to participants' previous familiarity with videos in any mood induction protocol. Finally, and most importantly, the ratings collected here were collected at a single point in time, after the video. This more closely measures a participants' immediate emotional response, and does not measure changes in mood over time. To study the longer-lasting changes in mood, participants should provide self reports at baseline, after the video, and after the main task, to have a better indication of how their mood changed throughout the course of the experiment.

## **Conclusion**

These videos were successful in eliciting positive, negative, and neutral responses in varying degrees of arousal in young adult participants. We included videos of real-life events and some animated films to complement current film databases that are used for mood induction. Many of the positive videos were familiar to participants, but this did not decrease self-reported levels of valence or arousal. Researchers are encouraged to use these clips in their own work and to continue building on this database in future.

**Study 2B. Effects of Mood Manipulation on Emotional Memory Biases in Young and Older  
Adults**

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### Abstract

Older adults tend to be in a more positive mood than young adults. They also tend to remember positive information more often than negative information, but the link between their positive mood and their positive memory has rarely been explored. In the current study, we experimentally manipulated young and older adults' moods to test for effects on emotional memory. We hypothesized that participants induced into a positive mood would recall more positive than negative pictures, and those induced into a negative mood would recall more negative than positive pictures (i.e., we expected mood-congruent memory effects). For mood manipulation, young ( $n = 147$ ) and older ( $n = 111$ ) adults viewed a positive, negative, or neutral video lasting 3 minutes. To validate the mood induction protocol, participants reported their level of valence (unhappy to happy) and arousal (calm to excited) from 0 to 100 using the affective slider (Betella & Verschure, 2016) at baseline, after the video, and after the memory task. Participants also completed the Positive and Negative Affect Schedule (Watson et al., 1988) at the start and end of the session. After the video, participants completed an incidental encoding task of 30 pictures (10 positive, 10 negative, 10 neutral), followed by free recall. Overall, the mood manipulation was successful in changing people's self-reported valence, yet it had little impact on self-reported arousal. The memory task revealed a consistent negativity bias in young adults, which was strongest after viewing a positive video. Older adults showed a memory preference for positive over neutral pictures, but only after viewing a negative video. Therefore, the results showed some evidence of mood-incongruent memory in both age groups. We discuss the implications of mood on emotional memory, and explain the positivity effect in aging as the absence of a negativity bias that is otherwise robust in young adults.

*Keywords:* mood induction, films, emotion, memory, aging, positivity effect

## Introduction

Mood can influence a person's memory and other cognitive functions (for reviews, see Blaney, 1986; Bower, 1987; Eich et al., 2008). It can be understood as a background affective tone capable of influencing how brief emotional experiences are processed and remembered (Rottenberg et al., 2007)<sup>10</sup>. Information that is emotionally congruent with a person's mood may receive greater attention and more elaborative processing than neutral or emotionally-incongruent material (Eich et al., 2008). This can lead to mood-congruent memory (MCM) effects, whereby participants who are in a positive mood at encoding better remember positive stimuli, and participants who are in a negative mood at encoding better remember negative stimuli. Mood-congruent memory can also occur in a number of other circumstances (e.g., when mood at retrieval is congruent with material), but is strongest when mood during encoding matches the affective tone of the target stimuli (for a review, see Singer & Salovey, 1988).

From middle age to older adulthood, positive affect seems to increase (Gana et al., 2015; Kunzmann et al., 2000) and negative affect seems to decrease, independent of health (Kunzmann et al., 2000). In parallel, older adults seem to remember positive information more often, and negative information less often, than young adults (i.e., the aging positivity effect). Indeed, in past studies of the aging positivity effect in memory, older adults have consistently reported being in a more positive mood than young adults at the start of the experiment. This has manifested as older adults reporting higher positive affect (e.g., Mather & Knight, 2005), lower negative affect (e.g., Charles, Mather, & Carstensen, 2003<sup>11</sup>; Grühn, Scheibe, & Baltes, 2007;

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<sup>10</sup> In this paper, the terms *mood*, *affect*, and *emotion* are used interchangeably and are considered synonymous of one another (Knight, Rastegar, & Kim, 2016).

<sup>11</sup> In experiment 2 (mood was not measured in experiment 1).

Spaniol, Voss, & Grady, 2008<sup>12</sup>), or both (e.g., Emery & Hess, 2008, 2011; Fernandes, Ross, Wiegand, & Schryer, 2008; Fung, Isaacowitz, Lu, & Li, 2010; Mather & Knight, 2005; Tomaszczyk, Fernandes, & Macleod, 2008), when compared to young adults. Moreover, older adults have often reported fewer depressive symptoms than young adults (Charles et al., 2003; Fung et al., 2010; Mather & Knight, 2005; Mickley & Kensinger, 2009).

So far, the way that researchers have typically examined the influence of mood on the positivity effect is to include mood as a covariate in their analysis. The results are divergent and inconclusive. Mood has sometimes correlated with memory (Barber et al., 2016; Charles et al., 2003), and mediated some of the effects of age on memory (Emery & Hess, 2008), whereas other times it did not (Fernandes et al., 2008; Mather & Knight, 2005; Tomaszczyk et al., 2008). In one such study, Barber et al. (2016) experimentally manipulated time perspective (using a text priming task) and found that mood suppressed, rather than mediated, the effects of time horizons on the positivity effect (i.e., the relationship between time and positivity of recall increased after controlling for mood). Yet this did not preclude the role of mood in the positivity effect. In fact, mood was just as strong a predictor of the positivity of recall as was time horizons ( $\beta = .32$  for both factors in the regression analysis). Mood and time horizons may therefore produce competing effects on the positivity of recall (see Thesis Study 3). Across these past studies, the procedures varied enormously (e.g., encoding task/instructions, memory test delay and type) as did their support for or against the positivity effect, thus limiting one's ability to determine the source of these inconsistent findings.

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<sup>12</sup> In experiments 1 and 2.

Even better than observing mood-cognition associations would be experimental evidence, in which one manipulated mood. One of the few studies to experimentally examine this question found partial support for the mood-congruent hypothesis (Knight et al., 2002). In this study, older adults induced into a sad mood recalled fewer positive words than when they were induced into a neutral mood. However, the sad mood induction did not alter the immediate recall of negative words in either young or older adults. Memory for neutral words was not tested in this study, therefore it was not possible to examine the emotional enhancement of memory more broadly (which is a relative difference in recall between emotional and neutral stimuli). Moreover, inducing a positive mood would allow for a direct examination of the mood-congruent hypothesis by testing whether it is only participants who are in a positive mood who show a positive memory bias. A full experimental design contrasting both positive and negative mood inductions and their effects on memory for emotional and neutral stimuli is needed to thoroughly test whether mood influences the positivity effect in aging.

### **Current Study**

The goal of the current study was to directly test the mood-congruent hypothesis of the positivity effect. Oftentimes, researchers do not address this question directly but instead treat mood as an extraneous variable to avoid and control. Yet, the robust differences in mood between young and older adults in past studies (Emery & Hess, 2008, 2011; Fernandes et al., 2008; Fung et al., 2010; Mather & Knight, 2005; Tomaszczyk et al., 2008) warrant a thorough investigation based on procedures specifically targeting mood-congruent memory (MCM) effects. Peoples' moods can vary throughout the course of a day, which can be challenging for research. To exert greater experimental control, we used a mood induction protocol in which participants' exposure to emotion-eliciting videos could be controlled and randomized.

In the current study, we experimentally manipulated young and older adults' mood using positive, negative, or neutral video clips (from Thesis Study 2A), to examine the direct effect of mood on emotional memory in young and older adults. The current study uses methods designed to independently maximize MCM and positivity effects. First, memory was tested using free recall because this is more likely to encourage substantive (elaborative) processing, leading to MCM effects. Free recall also leads to stronger emotional biases, including the positivity bias, than recognition tests (e.g., Charles et al., 2003; Tomaszczyk, Fernandes, & Macleod, 2008). Second, mood induction was performed immediately prior to the encoding of emotional stimuli because encoding congruence (i.e., congruence between mood at encoding and the stimuli) produces more reliable MCM effects and as reviewed above, mood at encoding greatly differs between young and older adults. Third, the emotional and neutral pictures were presented in a mixed order to encourage the distinctive processing of emotional items (Thesis Study 1). For this study, a new set of video clips were selected from online sources and validated in a separate study of 80 university students prior to being used here (Thesis Study 2A). This new set of videos was created to avoid limitations of previous film databases (e.g., videos were often short in duration or obtained from well-known films such as *Bambi* or *When Harry Met Sally*).

The effectiveness of the mood manipulation technique was assessed using both behavioural and physiological measures. Participants self-reported their level of valence and arousal using a sliding scale. In addition, participant heart rate variability and cardiac impedance were collected throughout the experiment. Heart rate variability quantifies the electrical activation of the heart through changes in the timing between heart beat peaks and indicates parasympathetic nervous system activation. Whereas cardiac impedance considers the mechanics of the heart and informs us on sympathetic nervous system activation (Mindware Technologies,

2017). In the present paper, all videos were 3 minutes in duration, sufficient for measuring physiological responses (Munoz et al., 2015). Together, these measures were included to help inform us of a person's autonomic balance in response to the video manipulation.

According to the mood-congruent hypothesis, a mood-congruent memory advantage should appear for both young and older adults: both age groups should show increased memory for positive stimuli relative to negative and neutral stimuli when in a positive mood, and increased memory for negative stimuli relative to positive and neutral stimuli when in a negative mood. The current study also incorporates measures of future time perspective and emotion regulation to evaluate the predictions of Socioemotional Selectivity Theory (Carstensen et al., 1999; Charles et al., 2003), which is currently the most well-supported theory in the positivity literature.

## Methods

### Participants

The final sample comprised 147 young adults (17-27 years) and 111 older adults (56-91 years). The target number was 110 to obtain .80 power to test the within-between interaction (based on a priori power analysis for a small effect using G\*Power software; Faul, Erdfelder, Buchner, & Lang, 2009)<sup>13</sup>. Data from one additional older adult participant were excluded because of an incomplete session. Participants were screened for psychiatric or neurological conditions. They were also screened for depressive symptoms using the Centre for Epidemiologic Studies Depression scale (CES-D; Radloff, 1977). Older adults were further screened for possible cognitive impairments using the Montreal Cognitive Assessment (MOCA; Nasreddine et al.,

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<sup>13</sup> The initial target number of participants was 140 per group to obtain .90 power (calculated a priori), but we subsequently lowered the power estimate due to limited recruitment resources.

2005). Participants were randomly assigned to one of the three video conditions (neutral video, negative video, positive video). Demographic and questionnaire data per age group and video condition are presented in Table 6.

Table 6

*Questionnaire Data for Young and Older Adults by Mood Condition*

	Young			Older		
	Neutral	Negative	Positive	Neutral	Negative	Positive
<i>n</i>	55	48	44	38	39	34
<i>*Age</i>	18.38 (1.39)	19.29 (1.69)	18.80 (1.77)	70.63 (7.35)	69.87 (6.64)	71.62 (6.67)
<i>*Education</i>	12.38 (0.68)	12.92 (1.40)	12.64 (1.18)	17.08 (2.50)	17.23 (3.08)	16.24 (2.97)
<i>†MOCA</i>	-----	-----	-----	27.92 (2.01)	26.64 (2.29)	26.76 (2.26)
<i>*CES-D</i>	19.33 (9.93)	18.27 (10.53)	18.44 (10.55)	7.66 (6.20)	8.49 (7.10)	10.97 (9.64)
<i>*FTP-total</i>	52.02 (8.73)	50.63 (9.60)	51.40 (9.41)	39.66 (11.11)	40.21 (12.69)	38.21 (14.73)
<i>*FTP-ambiguous</i>	16.89 (5.53)	14.77 (5.82)	15.09 (4.13)	12.74 (4.08)	13.03 (4.45)	13.50 (5.00)
<i>ERQ-appraisal</i>	29.82 (6.75)	30.21 (6.89)	29.33 (5.07)	32.03 (6.45)	30.92 (5.53)	30.50 (5.97)
<i>*ERQ-suppression</i>	15.18 (4.51)	15.33 (5.73)	14.23 (4.57)	11.63 (4.69)	12.74 (4.94)	12.62 (4.77)

*Note.* Mean and SD for age (in years), education (in years), Montreal Cognitive Assessment (MOCA), Centre for Epidemiologic Studies Depression scale (CES-D), Future Time Perspective total score (FTP-total), Future Time Perspective ambiguous subscore (FTP-ambiguous), Emotion Regulation Questionnaire cognitive appraisal component (ERQ-appraisal) and emotional suppression component (ERQ-suppression). \*Significant effect of Age Group at  $p < .0001$ . †Significant effect of Mood Condition at  $p < .05$ .

Young adults were recruited through the University of Ottawa's undergraduate research pool and received course credit for their participation. Older adults were recruited from the Ottawa area and received \$20 for their participation. Participants provided their written informed consent and completed the study in English or French. This study was approved by the University of Ottawa Research Ethics Board (#H12-14-14).

### **Stimuli**

A set of 10 positive, 10 negative, and 10 neutral pictures were selected from the International Affective Picture System (P. J. Lang et al., 2008), the Geneva Affective Picture Database (Dan-Glauser & Scherer, 2011), and the internet. Four additional images (1 positive, 1 negative, 2 neutral) were selected as buffer images. The neutral pictures depicted domestic scenes of people and objects around the house (e.g., a man painting a room or an ironing board). The interrelatedness of pictures was evaluated in a pilot study (Ack Baraly et al., 2019; Thesis Study 1) by asking participants ( $n = 19$ ; 17 women; 18-24 years old) to rate the extent to which pairs of pictures from the same category were semantically related from 1 (not at all related) to 7 (extremely related), as per Talmi and McGarry (2012). Participants were instructed to concentrate on the content of pictures rather than their physical similarities. The average interrelatedness was similar between positive, negative, and neutral pictures. The same pilot participants also rated the valence and arousal of pictures on a 9-point scale using the Self Assessment Manikins from P. J. Lang et al. (2008). The three types of pictures differed in their level of valence, and the two emotional categories were matched in terms of arousal (see Table 7).

Table 7

*Mean (SD) Ratings of Pictures*

	<b>Valence</b>	<b>Arousal</b>	<b>Semantic Interrelatedness</b>
<i>Positive</i>	2.96 (1.86)	4.67 (2.55)	3.99 (2.19)
<i>Negative</i>	7.68 (1.59)	4.56 (2.66)	3.88 (2.25)
<i>Neutral</i>	5.01 (1.16)	7.19 (2.11)	3.84 (2.08)

*Note.* Participants rated valence from 1 (happy) to 9 (unhappy) and arousal from 1 (excited) to 9 (calm), similar to P. J. Lang et al. (2008). The mean semantic interrelatedness of pairs of pictures was measured from 1 (not at all related) to 7 (extremely related), as per Talmi & McGarry (2012).

### **Mood Manipulation**

Participants were presented with one of six video clips to induce an emotional or neutral state. Two positive, two negative, and two neutral videos were selected from our pilot study of 29 videos (see Thesis Study 2A). Two videos were selected for each category to reduce any possible confounding effects specific to unique attributes in individual videos. One animal and one human video was selected for each of the emotional categories although the neutral videos contained only humans (due to the generally positive ratings of the ‘neutral’ animal videos). All videos were trimmed to exactly 3 minutes in length using Filmora software.

To validate the mood induction, participants self-reported their level of valence (unhappy to happy) and arousal (calm to excited) from 0 to 100 using the affective slider (Betella & Verschure, 2016) at baseline, after the video, and after the memory task. Participants also indicated (*yes* or *no*) whether they had seen the video prior to the study. At the end of the experiment, participants were asked whether they could guess the research hypotheses to ensure that they were not responding based on their perceived goals of the study.

We also recorded electrocardiography (ECG) and impedance cardiography (ZCG) from 71 young adults and 63 older adults using BioLab Acquisition software and hardware (Mindware Technologies). To this end, six disposable sensors were placed on participants at the start of the experiment. For ECG, sensors were placed below the left rib and on the right clavicle. For ZCG, sensors were placed on the jugular notch, xiphoid process, and on the back above the jugular notch and below the xiphoid process. From the ECG signal, we included the following indicators of heart rate variability (HRV): mean heart rate (HR), high frequency (HF)/RSA<sup>14</sup> power, HF/RSA<sup>15</sup> peak power frequency, low frequency (LF)/HF ratio, Root Mean Square of the Successive Differences (RMSSD). The first four measures are frequency-domain variables whereas the last one (RMSSD) is a time-domain variable. From the ZCG signal, we obtained two values: left ventricular ejection time (LVET) and pre-injection period (PEP). All physiology data were processed and values calculated using HRV Analysis 3.1.2 and IMP Analysis 3.1.2 software. The ECG and ZCG signals were visually inspected for noise and abnormalities by the first author (KTAB) and double checked by a student volunteer. Four time periods of 3 minutes each were analyzed: baseline, during the video, after the video, and after the memory task.

## Procedures

At the start of the experiment, all participants were asked to sit for 3 minutes to relax. This served as a baseline recording for those who were connected to the ECG and ZCG. Participants then completed the first affective slider on valence and arousal (Betella & Verschure, 2016), followed by the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988), which measures their level of positive and negative affect by indicating to what extent

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<sup>14</sup>This measure accounts for Respiratory Sinus Arrhythmia (RSA) to remove variation caused by respiration.

<sup>15</sup>Idem.

they currently feel each of 20 emotional adjectives (10 positive, 10 negative) on a scale from 1 (very slightly or not at all) to 5 (extremely). We then presented participants with one of the six videos randomly. They were instructed to watch the video as if they were watching a television. After the video, they once again remained seated for 3 minutes with no task to complete (i.e., to obtain the post-video ECG and ZCG values). Then they completed the second affective slider followed by the memory task. The memory task contained three parts: an encoding phase of 30 target images, an arithmetic distraction task (1 minute), and a final written recall test (5 minutes). Target pictures appeared on the screen for 4 s each in a mixed-valence random order, followed by a white inter-stimulus screen for 500 ms. Two buffer images appeared at the start and end (1 negative, 1 positive, 2 neutral) to minimize the potential effects of primacy and recency. After the picture presentation, participants completed simple arithmetic calculations (e.g., “5+2=?”) during 1 minute. Participants were then given 5 minutes to write down brief descriptions of as many pictures as they could remember. They could take up to an additional 5 minutes for the free recall task as needed. At the end of the memory task, participants remained seated for 3 minutes so we could record their ECG and ZCG one final time. Afterward, participants reported their current level of valence and arousal using the final affective slider and completed a second PANAS. At this point, participants were given a break before continuing with the remaining tasks.

Participants were asked to complete the MOCA, CES-D, and Future Time Perspective (FTP) scales. Two FTP scores were calculated. First, a FTP total score was calculated using the entire scale from Carstensen and Lang (1996). Second, a FTP ambiguous score was calculated using four ambiguous statements from Brothers, Chui, and Diehl (2014) to specifically measure ambiguous time orientation. Participants also completed the Emotion Regulation Questionnaire (Gross & John, 2003), measuring both cognitive appraisal and emotional suppression. At the end

of the session, we showed participants a funny dog video to minimize possible deleterious effects of the video and picture tasks, followed by a thorough debriefing. The entire session lasted up to two hours.

### **Statistical analyses**

To score the free recall data, we used the same criteria as in Ack Baraly et al. (2019; Thesis Study 1). That is, each picture was considered a correct match if the rater could identify which picture was being described. The first author (KTAB) scored all of the recall data for young and older adults. A second rater double scored all of the young adult data and another rater double scored the data from 70 older adults (i.e., 63% of the sample). We calculated inter-rater reliability using Pearson's correlations for each age group and picture category separately.

Between-subject ANOVAs of Age (young, older) and Mood Condition (negative, positive, neutral) were conducted with the following dependent variables: Age, Education, CES-D, FTP-total, FTP-ambiguous, ERQ-appraisal, ERQ-suppression, or MOCA (older adults only). These variables all assess traits that should not be influenced by the mood manipulation. We expected differences between young and older adults on many, if not all of these variables. The purpose of the ANOVA was to ensure that young and older adults' reports did not change based on the mood condition (i.e., they were all randomly assigned to a mood condition so no main effect or interaction should be seen with mood condition).

We compared participants' past familiarity with the videos by using an independent-samples non-parametric analysis (Kruskal-Wallis test)<sup>16</sup> to test whether the positive, negative, or neutral videos were more familiar to participants. This test was performed separately for the

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<sup>16</sup> A non-parametric analysis was required because of the non-normality of familiarity responses in the negative and neutral conditions.

young and older adults. Only 0% to 2% of participants had previously seen the negative or neutral videos prior to the experiment. Therefore, subsequent analyses only included participants from the positive video condition. For these participants, we calculated the correlation between their video familiarity and self-reported emotional responses (valence, arousal, PANAS subscales) and recall (for each of the picture types).

Then, we conducted two set of analyses on the self-reported measures of valence, arousal, and positive/negative affect (PANAS). We performed a log transformation to normalize the negative PANAS scores and used these transformed data in the subsequent analyses. First, we tested whether baseline differences existed between young and older adults. To this end, we performed an independent samples *t*-test comparing Age Groups (young, older) in their self-reported valence, arousal, and PANAS scores (positive and negative). Second, to ensure that the mood manipulation was effective, a repeated measures ANOVA with Age (young, older) and Mood Condition (neutral, negative, positive) as between-subjects factors and Time (baseline, post-video, post-memory) as a within-subjects factor was performed on the ratings of valence and arousal. No differences between mood conditions should be observed at baseline although significant differences in valence and arousal should appear at the second and third time points. Similarly, no differences in positive and negative affect (measured with the PANAS) should exist between the mood conditions at baseline, although differences should appear after the video and memory task. To analyze the physiological data (measures of heart rate variability and cardiac impedance), we performed a series of nonparametric analyses (Mann-Whitney U) due to violations in the normality of the distributions. These analyses were conducted separately for young and older adults, comparing participants in the three mood conditions on the different physiological measures (heart rate variability: mean heart rate, HF power, HF peak power

frequency, LF/HF ratio; cardiac impedance: LVET, PEP). The following predictions were made: Although there should exist no physiological differences across the mood conditions at baseline, differences should appear between the emotional and neutral conditions at the second and third time points.

Then, a 2 x 3 x 3 mixed ANOVA was performed with Age (young, older) and Mood (positive, negative, neutral) as the between-subjects factors and Picture Type (positive, negative, neutral) as the within-subjects factor, on the total number of pictures correctly recalled<sup>17</sup>. All post hoc comparisons were performed using a Holm-Bonferroni adjusted alpha level. Crucially, we tested whether an interaction existed between Mood and Picture Type because the direction of the memory bias (positive or negative) should vary between the mood conditions. This also allowed us to test whether the effects of mood on recall were the same in both age groups.

To directly compare the magnitude of the positivity bias across age groups and conditions, we also calculated a positivity of recall score as per Barber et al. (2016): the number of correctly recalled negative pictures was subtracted from the correctly recalled positive pictures, the sum being divided by the total number of pictures recalled  $[(\text{positive} - \text{negative}) / (\text{positive} + \text{negative} + \text{neutral})]$ . We were then able to use a multiple linear regression analysis to test whether the self-reported measures significantly predicted the positivity of recall in young and older adults. First, we calculated the Pearson's correlations between positivity of recall and the following variables: Mood Condition, Age Group, valence (3 time points), arousal (3 time

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<sup>17</sup> We did not include any of the demographic or questionnaire responses as covariates in this analysis because there was no main effect or interaction by Mood Condition. There is insufficient statistical power to include all variables with age-group differences in the mixed ANOVA. If we include a few key variables as covariates, CES-D and the two time perspective scales (because these test hypotheses of mood congruence and SST), the results of the analysis remain the same. If anything, their inclusion brings the trending effects closer to significance. For consistency and simplicity, we do not include these covariates in the ANOVA.

points), PANAS positive and negative affect (baseline, post-memory task), FTP-Total, FTP-Ambiguous, ERQ-Appraisal, ERQ-Suppression, and CES-D. The variables that significantly correlated with positivity of recall were inputted into a multiple regression analysis. The advantage to this analysis is that it allowed us to simultaneously compare the predictive weight of each variable, while inputting a single dependent variable (positivity of recall) that reflects the strength and direction (positive or negative)<sup>18</sup> of one's emotional memory bias.

## Results

### Data Screening

The data were screened for outliers and violations of normality using the Kurtosis and Skewness values in SPSS. The demographic and questionnaire data were normally distributed with no outliers, except for age and education which were both positively skewed in young adults. This is expected because university students are predominantly of the same age and education. Free recall data were also normally distributed with no outliers. The distribution of scores for valence and arousal were normal (Kurtosis and Skewness values 1.5 or lower). However, the interquartile range of arousal scores for older adults was very small, leading to a dozen outlying scores identified in SPSS. Next, we calculated the z-scores for each arousal time point for older adults, and all scores were below 3. Therefore, all data were retained. The PANAS positive subscale had normally distributed data with no outliers, but the negative subscale (both time points) were positively skewed so we performed a log transformation to normalize the data. The Kurtosis values for the physiological measures were high (above 3) so we tried applying a log and square root transformation but these could not resolve the abnormal

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<sup>18</sup> Based on the calculation used, a positive value reflects a positivity bias and negative value reflects a negativity bias.

distributions in the physiological measures. As a result, we used nonparametric statistics for the analysis. There were no violations in sphericity in any of the analyses.

There was also a number of self-reported valence and arousal responses missing in the sample. Missing data occurred in 14 young and 13 older adults where there was at least one response of valence or arousal missing. Missing data for valence and arousal totaled 2.27% in young adults and 2.85% in older adults<sup>19</sup>. These scales serve as a behavioural validation of the mood manipulation technique and for that reason, it did not seem appropriate to replace the missing data (e.g., with the mean score). As a result, participants with missing data were removed from the analysis.

### **Inter-rater reliability**

Pearson's correlations between the two raters for young adults were high for negative ( $r = .95$ ), positive ( $r = .96$ ), and neutral ( $r = .93$ ) pictures. The correlations between the two raters for older adults was also high for negative ( $r = .93$ ), positive ( $r = .85$ ), and neutral ( $r = .94$ ) pictures. The primary rater (KTAB) triple scored all disagreements to ensure accuracy and consistency across the ratings.

### **Demographics and Questionnaire Data**

Mean responses differed significantly between age groups for: Chronological Age [ $F(1, 257) = 7732.35, p < .0001$ ], Education [ $F(1, 257) = 264.50, p < .0001$ ], CES-D [ $F(1, 255) = 67.22, p < .0001$ ], FTP-total [ $F(1, 256) = 75.32, p < .0001$ ], FTP-ambiguous [ $F(1, 256) = 15.95, p < .0001$ ], and ERQ-suppression [ $F(1, 256) = 17.84, p < .0001$ ]. Young adults were (of course)

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<sup>19</sup> This was calculated as follows. Young adults: 20 missing cells / 882 total cells (147 young adults x 2 measures x 3 time points). Older adults: 19 missing cells / 666 (111 older adults x 2 measures x 3 time points).

younger, with fewer years of education, and reported more depressive symptoms than older adults. They also viewed their future as open-ended yet ambiguous, and they suppressed their emotions more than older adults.

There was also a main effect of Video Condition for the MOCA [ $F(2, 109) = 3.94, p = .022$ ] but not for any other measure. Older adults who viewed the negative video performed lower on the MOCA than those who viewed the neutral video (Bonferroni-correct  $p = .035$ ). The MOCA was not administered to young adults and was therefore not inputted as a covariate in the analysis. No other factor was influenced by Video Condition and therefore no other factor was considered as a covariate in subsequent analyses of variance.

### **Video Familiarity**

Young and older adults were more likely to have previously seen the positive video than the negative or neutral video [young: Kruskal-Wallis  $H(2) = 18.99, p < .0001$ ; older: Kruskal-Wallis  $H(2) = 6.92, p = .031$ ; Table 8]. Familiarity with the positive video did not significantly correlate with any of the self-reported emotional responses or recall, and was therefore not considered in subsequent analyses.

### **Self-Reported Emotional Responses**

**Baseline.** At baseline, older adults reported more positive valence [ $t(248) = 4.53, p < .0001$ ] and positive affect [ $t(255) = 5.15, p < .0001$ ], and less negative affect [ $t(242) = 7.42, p < .0001$ ], compared to young adults (Table 8). Older adults also seemed to report higher levels of arousal [ $t(244) = 2.08, p = .038$ ], but this difference was not significant when controlling for multiple  $t$ -tests (alpha  $.05/4 = .0125$ ).

Table 8

*Mean (SD) Self-Reported Valence, Arousal, and Positive and Negative Affect by Age Group and Mood Condition*

		Young Adults			Older Adults		
		Mood Condition					
		Neutral	Negative	Positive	Neutral	Negative	Positive
<b>Total N</b>		55	48	43	38	39	34
<b>Familiarity</b>		0%	2%	21%	0%	0%	9%
<b>Valence</b>	<i>n</i>	51	44	43	37	39	32
	Baseline	64.29 (17.24)	69.05 (16.05)	69.37 (17.82)	80.95 (14.95)	74.49 (20.09)	76.38 (17.38)
	Post-Video	55.02 (16.66)	32.91 (19.31)	77.19 (16.58)	64.59 (22.22)	32.92 (21.60)	79.13 (26.77)
	Post-Memory	54.02 (17.37)	49.98 (16.43)	55.42 (19.79)	68.03 (18.96)	56.82 (21.25)	58.44 (18.25)
<b>Arousal</b>	<i>n</i>	50	44	43	37	36	27
	Baseline	47.86 (20.85)	44.39 (20.79)	45.40 (20.56)	49.78 (24.12)	55.58 (17.10)	49.48 (22.44)
	Post-Video	37.64 (19.86)	42.59 (18.54)	51.16 (21.32)	47.89 (20.98)	51.56 (19.41)	54.70 (32.81)
	Post-Memory	44.54 (19.22)	45.70 (16.59)	41.98 (19.40)	57.59 (22.05)	50.56 (15.85)	53.37 (18.18)
<b>PANAS Positive</b>	<i>n</i>	55	48	43	38	39	34
	Baseline	29.87 (7.40)	29.35 (6.22)	28.47 (7.47)	34.21 (7.49)	33.49 (6.75)	34.15 (8.04)
	Post-Memory	26.93 (8.27)	27.23 (7.72)	25.70 (8.26)	33.55 (7.56)	31.54 (7.78)	33.79 (7.90)
<b>PANAS Negative</b>	<i>n</i>	55	48	43	38	39	34
	Baseline	16.58 (6.88)	15.44 (5.04)	14.88 (6.00)	12.11 (3.14)	11.28 (1.91)	12.32 (3.08)
	Post-Memory	15.16 (5.55)	15.81 (5.93)	16.02 (7.13)	12.29 (3.14)	12.10 (2.49)	13.18 (4.54)

*Note.* Familiarity represents the percentage of participants who had seen the video before the study. Valence was rated from 0 (unhappy) to 100 (happy) and arousal was rated from 0 (calm) to 100 (excited). PANAS = Positive and Negative Affect Schedule.

**Valence (scale from 0 to 100).** Self-reported valence differed significantly between the two Age Groups [ $F(1, 240) = 15.63, p < .0001, \eta_p^2 = .06$ ]: Older adults reported higher (i.e., more positive) levels of valence than young adults (mean valence of 65.29 vs. 58.48, respectively). There was also a main effect of Mood Condition [ $F(2, 240) = 29.38, p < .0001, \eta_p^2 = .20$ ], with responses being lower in the negative condition ( $M = 52.69$ ), higher in the neutral condition ( $M = 64.48$ ), and highest in the positive condition ( $M = 69.32$ ). These main effects were characterized by an Age Group x Mood Condition interaction [ $F(2, 240) = 3.07, p = .048, \eta_p^2 = .03$ ]. Whereas young adults reported different levels of valence in each condition ( $ps < .05$ ), older adults reported lower valence in the negative condition only ( $ps < .0001$ ) and equally high valence in both positive and neutral conditions ( $p > .90$ ). This suggests that participants generally responded as expected to the video manipulation, with the exception of older adults responding positively to the neutral condition. In addition, there was a main effect of Time [ $F(2, 480) = 81.13, p < .0001, \eta_p^2 = .25$ ] because mean valence was significantly different between Time 1 and Time2 ( $p < .0001$ ) and between Time 1 and Time 3 ( $p < .0001$ ), but not between Time 2 and Time 3 ( $p = .71$ ). This was influenced by a Time x Mood Condition interaction [ $F(4, 480) = 52.30, p < .0001, \eta_p^2 = .30$ ]. At baseline, valence was similar in all three conditions ( $ps > .40$ ). After the video, participants reported lower valence in the negative condition, higher valence in the neutral condition, and even higher valence in the positive condition ( $ps < .0001$ ). After the memory task, valence was once again similar in all three conditions ( $ps > .05$ ). Participants generally started the experiment in a relatively good mood at baseline, then after viewing the video their mood changed based on the condition they were assigned to, and by the end of the memory task most participants were in a more neutral mood. The three-way interaction of Age Group x Mood Condition x Time was not significant.

**Arousal (scale from 0 to 100).** Self-reported arousal differed significantly between the two Age Groups [ $F(1, 231) = 14.31, p < .0001, \eta_p^2 = .058$ ]: On average, older adults reported higher levels of arousal than young adults ( $M = 52.25$  vs.  $44.52$ , respectively). There was also a Mood Condition x Time interaction [ $F(2, 462) = 3.81, p = .005, \eta_p^2 = .032$ ]. At baseline, arousal was similar in all three conditions ( $ps > .70$ ). Then, participants reported significantly higher arousal after the positive video than after the neutral video ( $p = .003$ ), yet they reported similar levels of arousal after the negative and neutral videos ( $p = .07$ ), and negative and positive videos ( $p = .11$ ). After the memory task, arousal was once again similar in all three conditions ( $ps > .40$ ). This suggests that the positive video led to the greatest increase in self-reported arousal, when averaging young and older adult responses together.

**Positive Affect (PANAS positive subscale).** Self-reported positive affect differed significantly between the two Age Groups [ $F(1, 251) = 36.57, p < .0001, \eta_p^2 = .127$ ]. On average, older adults reported higher positive affect than young adults ( $M = 33.43$  vs.  $27.98$ , respectively). Positive affect also differed significantly between the two Times. In general, positive affect was higher at baseline and lower by the end of the memory task ( $M = 31.30$  vs.  $29.37$ , respectively). There was also an Age Group x Time interaction [ $F(1, 251) = 8.04, p = .005, \eta_p^2 = .031$ ]. However, post-hoc paired samples  $t$ -tests showed that both Age Groups reported significantly higher positive affect at baseline than at the end of the memory task [Young adults:  $t(145) = 6.75, p < .0001$ ; Older adults:  $t(110) = 2.49, p = .014$ ]. Descriptively, the mean difference between time points was greater in young than in older adults, suggesting that young adults' positive affect decreased more.

**Negative Affect (PANAS negative subscale).** Self-reported negative affect differed significantly between the two Age Groups [ $F(1, 251) = 40.89, p < .0001, \eta_p^2 = .140$ ]. On average,

young adults reported higher negative affect than older adults ( $M = 15.67$  vs.  $12.19$ , respectively). There was also a significant Mood Condition x Time interaction [ $F(2, 251) = 3.14$ ,  $p = .045$ ,  $\eta_p^2 = .024$ ]. Post-hoc paired samples  $t$ -tests compared the two Times for each Mood Condition separately, using a Bonferroni-corrected alpha of  $.017$  ( $.05$  alpha / 3 contrasts). Using the corrected alpha, there was no significant difference between baseline and post-memory task for the negative [ $t(86) = 1.25$ ,  $p = .216$ ], positive [ $t(76) = 1.83$ ,  $p = .071$ ], or neutral conditions [ $t(92) = 1.97$ ,  $p = .051$ ].

### **Physiological Responses**

Data for one older adult were an outlier on HF Power and were removed for all time points. Mann-Whitney U analysis revealed no significant differences between the three Mood Conditions in young or older adult participants, on any of the physiological measures analyzed.

### **Memory**

The mixed ANOVA revealed a main effect of Mood Condition [ $F(2, 252) = 3.60$ ,  $p = .029$ ,  $\eta_p^2 = .028$ ] and Picture Type [ $F(2, 504) = 60.59$ ,  $p < .0001$ ,  $\eta_p^2 = .194$ ], and an Age Group x Picture Type interaction [ $F(2, 504) = 16.25$ ,  $p < .0001$ ,  $\eta_p^2 = .061$ ; see Figure 3]. The effect of Age Group was toward trend [ $F(1, 252) = 3.09$ ,  $p = .08$ ,  $\eta_p^2 = .012$ ] because young adults recalled slightly more pictures on average than older adults ( $M = 12.54$  vs.  $11.72$ , respectively). The three-way interaction between Age Group x Mood Condition x Picture Type was also toward trend [ $F(4, 504) = 2.05$ ,  $p = .087$ ,  $\eta_p^2 = .016$ ].

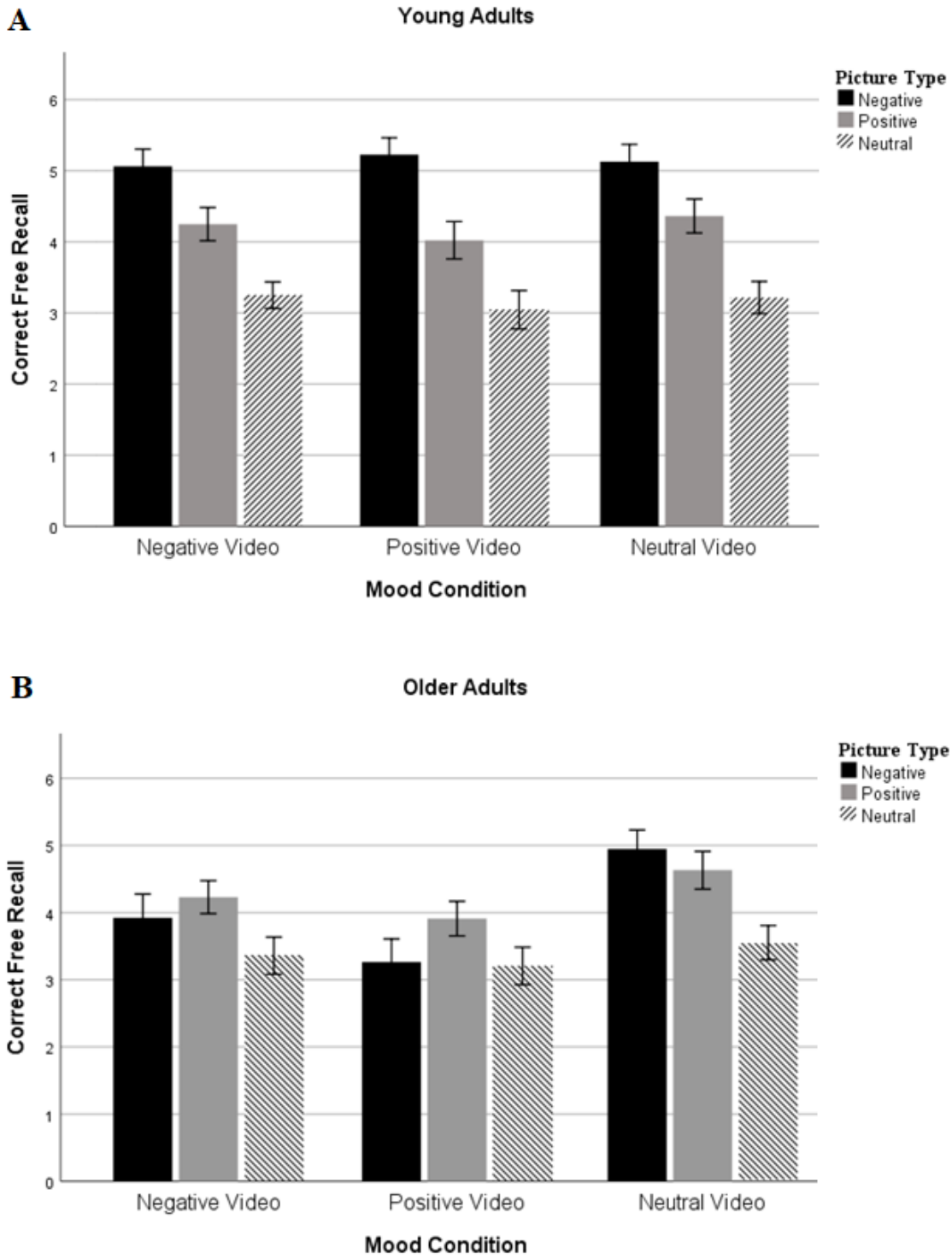


Figure 3. Mean correct recall in young adults (A) and older adults (B) after watching either a negative, positive, or neutral video.

First, participants in the neutral mood condition recalled more pictures in total than those in the positive mood condition ( $M = 4.31$  vs.  $3.78$ , respectively; Bonferroni-corrected  $p = .048$ ). There were no other differences in overall recall between Mood Conditions (negative vs. neutral conditions:  $p > .50$ ; negative vs. positive conditions:  $p > .80$ ). In regard to Picture Type, negative pictures were recalled more often than positive [ $t(257) = 3.28$ ;  $p = .001$ ] or neutral pictures [ $t(257) = 10.90$ ;  $p < .0001$ ], and positive pictures were recalled more often than neutral pictures [ $t(257) = 3.28$ ;  $p < .0001$ ]. This pattern of recall (negative pictures  $>$  positive pictures  $>$  neutral pictures) appeared in young adults, but was not present in older adults (Age Group  $\times$  Picture Type interaction). On the contrary, older adults recalled negative and positive pictures equally well [ $t(110) = 1.06$ ;  $p = .292$ ], both of which were better recalled than neutral pictures [negative vs. neutral:  $t(110) = 3.73$ ;  $p < .0001$ ; positive vs. neutral:  $t(110) = 5.44$ ;  $p < .0001$ ].

Because the three-way interaction (Age Group  $\times$  Mood Condition  $\times$  Picture Type) was central to our main hypotheses, we carried forward with a series of paired samples  $t$ -tests despite the interaction being toward significance ( $p = .087$ ). We used a Bonferroni-corrected alpha of  $.0056$  ( $.05$  alpha /  $9$  contrasts per age group). Statistically, the negativity bias (negative pictures  $>$  positive pictures) in young adults was only significant in the positive mood condition [ $t(43) = 4.32$ ;  $p < .0001$ ], but not in the negative mood [ $t(47) = 2.61$ ;  $p = .012$ ] or neutral mood conditions [ $t(54) = 2.47$ ;  $p = .017$ ]. In older adults, there was no statistically significant negativity or positivity bias because recall of both types of pictures was equal in all conditions ( $ps > .05$ ). However, in the negative mood condition, older adults recalled more positive than neutral pictures [ $t(38) = 3.22$ ,  $p = .003$ ], yet equal amounts of negative and neutral pictures [ $t(38) = 1.81$ ,  $p = .078$ ]. Furthermore, older adults recalled equal amounts of emotional and neutral pictures in the positive mood condition [negative vs. neutral:  $t(33) = 0.17$ ,  $p = .87$ ; positive vs. neutral:  $t(33)$

= 2.38,  $p = .023$ ], yet greater amounts of both positive and negative pictures versus neutral pictures in the neutral mood condition [negative vs. neutral:  $t(37) = 5.10, p < .0001$ ; positive vs. neutral:  $t(37) = 3.71, p = .001$ ]. In summary, there was an overall negativity bias in young adults (Age Group x Picture Type interaction), which was significant in the positive mood condition (when following up on the three-way interaction). In contrast, older adults did not show a negativity bias, and the presence of their positivity preference for positive over neutral pictures was significant in the negative mood condition (based on the three-way interaction post hocs).

A multiple linear regression was used to examine more specifically whether any of the self-reported measures significantly predicted emotional memory biases using the computed positivity of recall score (following the methods outlined in Barber et al., 2016). Data from one older adult were removed because the positivity of recall score was an extreme (positive) outlier. Only two independent measures were significantly correlated with positivity of recall (when using a Holm-Bonferroni corrected alpha): Age Group ( $r = .286, p < .0001$ ) and valence at baseline ( $r = .234, p < .0001$ ). These two independent variables were included in the regression model, with positivity of recall as the dependent variable. In the regression analysis, there was no concern of multicollinearity because tolerance values were greater than .90 and Variance Inflation Factor (VIF) values were smaller than 2. A significant regression equation was found [ $F(2,246) = 1405, p < .0001$ ], with an  $R^2$  of .103. Age Group ( $\beta = .262, p < .0001$ ) significantly predicted positivity of recall (Figure 4), but valence at baseline did not ( $\beta = .097, p = .124$ ; Figure 5). There was a slight shift in the frequency distributions of the positivity of recall scores between age groups, with older adults displaying slightly more positivity bias and young adults displaying slightly more negativity bias. This is consistent with there being a significant difference in positivity of recall scores between the two age groups [ $t(256) = 4.84, p < .0001$ ]. It

is interesting to note that both groups demonstrated a range of positive and negative memory bias.

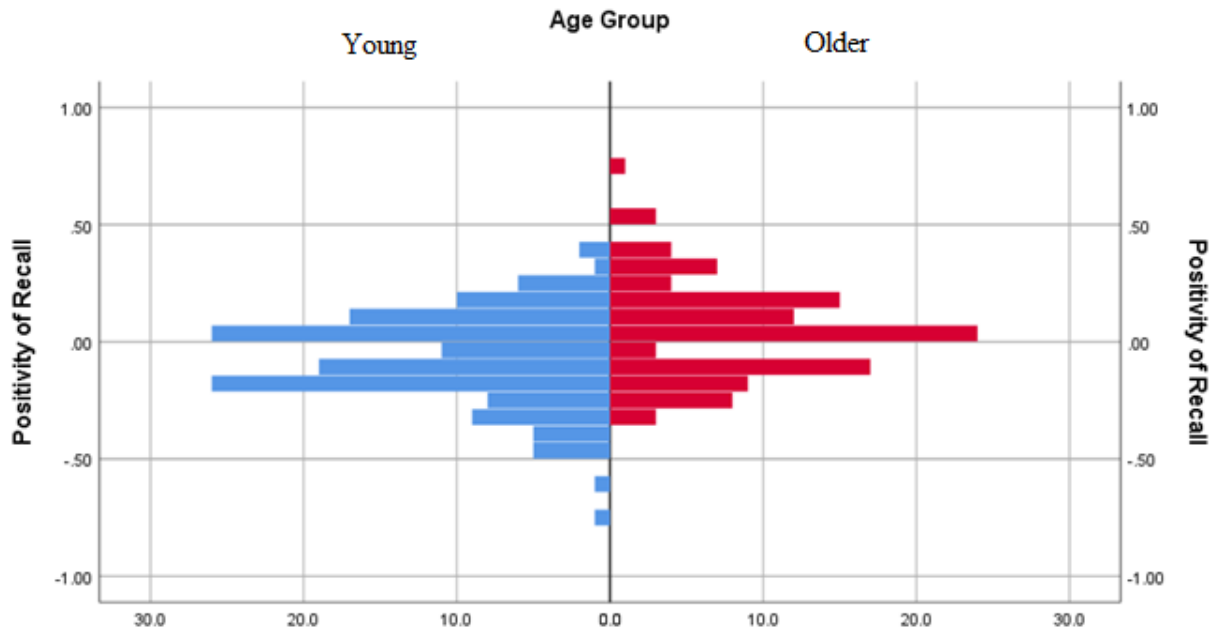


Figure 4. Frequency distribution of positivity of recall for young adults and older adults. Positive values reflect a positive memory bias and negative values reflect a negative memory bias.

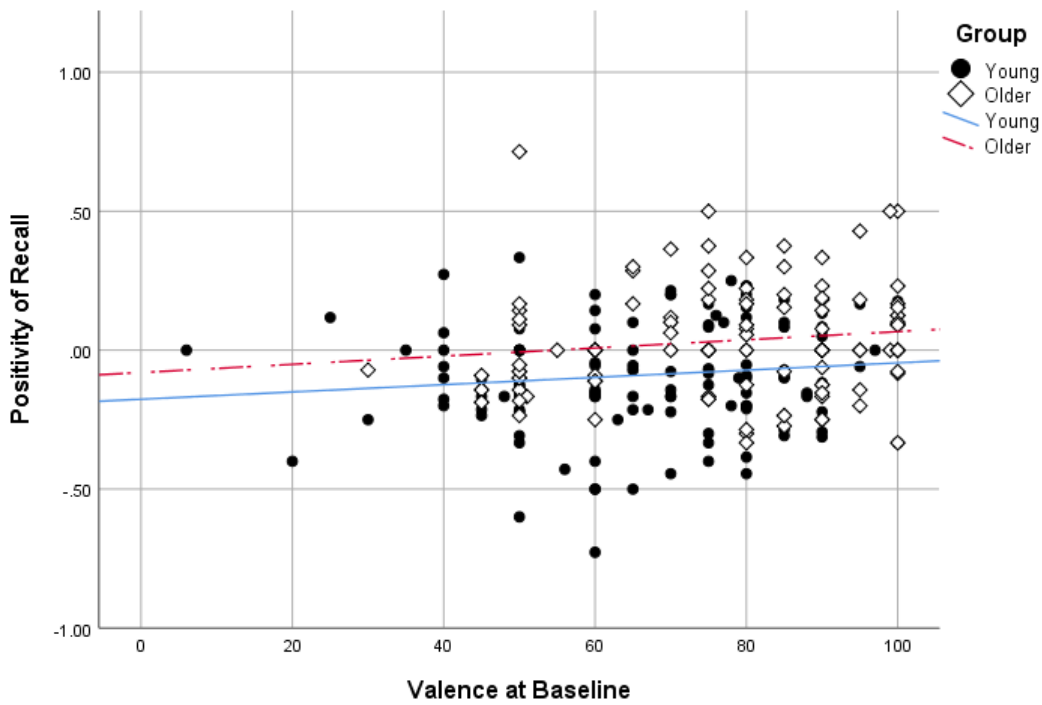


Figure 5. Positivity of recall scores as a function of valence at baseline in young adults and older adults.

## Discussion

Aging is associated with changes in mood, yet the impact of these changes on the positivity effect in memory has rarely been explored. In the current study, participants completed a mood induction protocol designed to promote either a negative, positive, or neutral mood. This was followed by a free recall picture memory task. The effectiveness of the mood induction protocol was assessed with self-reported behavioural measures (i.e., valence, arousal, and positive and negative affect; PANAS) and physiological measures (i.e., indicators of heart rate variability: mean HR, RMSSD, HF Power, HF Peak Power Frequency, LF/HF Ratio; and cardiac impedance: PEP and LVET). Overall, the mood induction protocol was successful in changing people's self-reported valence, yet it had little impact on self-reported arousal and physiological responses. Young adults seemed to show a consistent negative memory bias, which was strongest after viewing a positive video. Older adults did not show a negativity bias, but rather a memory advantage for positive over neutral pictures which varied somewhat by mood condition.

### Age Differences in Affect, Time Perspective, and Emotion Regulation

We argued that the positivity effect in aging might result, at least in part, from young and older adults differing in their mood at the start of an experiment. Indeed, young and older adults reported different levels of valence and affect: At baseline, older adults were more positive (valence and PANAS positive scales) and less negative (PANAS negative scale) than young adults. Furthermore, in comparison to young adults, older adults reported fewer depressive symptoms over the past week. Similar findings are reported in previous papers on emotional memory and aging (e.g., Charles et al., 2003; Emery & Hess, 2008, 2011; Fernandes et al., 2008; Fung et al., 2010, 2010; Mather & Knight, 2005, 2005; Mickley & Kensinger, 2009; Tomaszczyk et al., 2008). These results are consistent with lifespan studies showing linear

increases in positive affect and decreases in negative affect during adulthood and into older age (Gana et al., 2015; Kunzmann et al., 2000).

We also found that young adults viewed their future as more open-ended, albeit ambiguous, than older adults. This is normal because the average young adult has more time left in life than the average older adult, consistent with Socioemotional Selectivity Theory (Carstensen et al., 1999; Reed & Carstensen, 2012). However, this may also lead young adults to be uncertain of their future and view it as more ambiguous, especially for university students who have not yet started their career and post-academic life. We also found that young adults suppressed their emotions more than older adults, as indicated by higher scores on the Emotion Regulation Questionnaire (suppression component). This suggests that young adults adopt more maladaptive emotion regulation strategies than older adults. They may be more likely to suppress their feelings when dealing with stressful situations, which can lead them to also suppress feelings of positive emotions too (Gross & John, 2003). In fact, emotion suppression might have the opposite desired effect by leading them to feel even more negative emotions than those who do not use suppression (Gross & John, 2003). This is coherent with the observation of baseline differences in affect between the two groups. Overall, these results show that older adults were in a more positive mood at the start of the experiment, were more likely to engage in adaptive emotion regulation strategies in their daily life, and viewed their futures as more restrictive than young adults. These age group differences are consistent with both mood-congruent theory and SST. But the findings from the mood induction protocol and memory task are less clear.

### **Effectiveness of the Mood Induction Protocol**

Overall, the mood manipulation temporarily altered young and older adults' emotional state, as measured by self-reported valence (i.e., degree of pleasantness). There were no

differences in valence reported across the three video conditions at baseline. The videos induced the desired emotional response in young adults. They reported more of an unpleasant state after a negative video, a pleasant state after a positive video, and a neutral state after a neutral video. On the other hand, older adults reacted positively to both positive and neutral videos, and showed a significant unpleasant response to the negative videos. This is not surprising given that other authors have found that older adults respond more positively to neutral film clips (Fernández-Aguilar et al., 2018) and pictures (van Reekum et al., 2011), compared to young adults. In fact, in the present study, older adults reported higher (more positive) valence overall, compared to young adults. Once again, this supports our general findings that older adults reported higher positive affect and lower negative affect from the start of the experiment. Nonetheless, the video clips in the current study successfully elicited negative and positive emotions in both young and older adults, despite the neutral (control) condition being positively biased in older adults. This is an important advantage in the current study because previous work has shown that eliciting positive emotions can be challenging (Beaudreau et al., 2009; Fernández-Aguilar et al., 2018).

Interestingly, only the positive videos induced higher arousal compared to the neutral videos; arousal was otherwise equal between neutral and negative videos. The positive videos might have led to higher arousal because they depicted scenes of babies laughing and funny dogs, clips that were selected to target humour and amusement. These clips would land higher on the dimension of activation (Russell, 2003) than would the negative videos which targeted scenes of sadness and mild distress. We intentionally chose low activation negative videos because we believed sadness and distress would better reflect the sources of low mood in young adults (versus more intense negative emotions of fear or anger). Once again, older adults reported higher arousal levels than young adults when considering all conditions and time points. This

was unexpected because young adults are more likely to experience high arousal during positive and negative experiences, whereas older adults are more likely to experience lower arousal during positive experiences (Fernández-Aguilar et al., 2018; Keil & Freund, 2009). As has been pointed out elsewhere (Fernández-Aguilar et al., 2018), little work has been done to explore differences between discrete positive emotions in emotion-eliciting film sets, and comparisons between different age groups is even more rare. Some of the variability across studies could result from different discrete emotions being elicited, which should be considered in future studies.

Despite the mood manipulation successfully eliciting negative and positive emotional responses in young and older adults, there were a few limitations to this mood induction technique. First, the differences in valence and arousal did not last until the end of the experiment. By the end of the memory task, both age groups returned back to baseline levels in self-reported valence and arousal. This would mean that the emotions elicited in response to the video did not last until the end of the memory task. This shift back to baseline levels was also observed in Knight et al. (2002) using the Depressive Adjective Checklist as a measure for the sad mood induction. This may be more likely in studies involving an emotional memory task because viewing emotional stimuli can interfere with the emotion elicited by the video. Second, the measures of heart rate variability and cardiac impedance were inconclusive. Neither of these measures showed changes during or subsequent to viewing the different videos. Despite participants reporting behavioural changes in self-reported valence and arousal, there were no marked changes in their physiological responses. This could have been due in part to the low activation in the negative videos, explaining the lack of findings for the negative videos. Experiencing negative emotions seems to relate more strongly with autonomic responses than

positive emotions (Harrison, Kreibig, & Critchley, 2013). Most of the literature focuses on studies of *happiness*, yet other positive discrete emotions (e.g., amusement, contentment, pride, etc.) could result in different autonomic responses (Harrison et al., 2013). Overall, the physiological findings were unable to corroborate the self-report results and add further evidence to the effectiveness of the mood induction protocol.

### **Mood Induction and Memory**

The main purpose of this study was to test whether emotional memory biases in young and older adults could be explained by their moods. Contrary to our predictions, young adults consistently showed a negative bias in memory regardless of the mood manipulation. That is, their memory was always greatest for negative pictures, lower for positive pictures, and lower still for neutral pictures. A negativity bias in young adults is commonly reported in the literature (Baumeister et al., 2001; Carstensen & DeLiema, 2018; Reed et al., 2014). This was not the case for older adults, who recalled positive and negative pictures equally well (and better than neutral pictures) in all three mood conditions. Equal memory for positive and negative information in aging has also been shown in previous work (Kensinger, Garoff-Eaton, & Schacter, 2007).

Therefore, in neither age group was there an apparent mood congruence effect. In fact, follow-up analyses to the trending 3-way interaction (Age Group x Mood Condition x Picture Type) suggest there may have even been mood incongruent effects. The negativity bias in young adults was strongest and statistically significant only in the positive mood condition. Results were less clear in older adults. In the neutral mood condition, older adults showed a classic Emotional Enhancement of Memory (EEM) effect because their memory was greater for positive and negative pictures than for neutral pictures, with no advantage of one emotion over the other. In the positive mood condition, older adults recalled all pictures equally well and this EEM effect

disappeared. In the negative mood condition, however, older adults showed a positive EEM effect. They recalled more positive than neutral pictures, and equal amounts of negative and neutral pictures. Mood-incongruence may serve to regulate emotions (Forgas & Ciarrochi, 2002; Sedikides, 1994), which could explain why the positive EEM was most apparent in older adults in the negative mood condition. Indeed, previous work on attentional gaze showed that older adults were more likely to demonstrate mood-incongruent gaze toward faces when unhappy (Isaacowitz, Toner, Goren, & Wilson, 2008).

Taken together, the results of this study do not support a mood-congruent memory hypothesis of the positivity effect in aging. This is contrary to previous work (Knight et al., 2002) which reported some mood-congruent memory effects using a combined Velten and music induction technique. In their study, older adults recalled fewer positive words when they were induced into a sad mood than when induced into a neutral mood. The authors did not compare the relative difference in recall between positive and negative pictures within a mood condition, which would have allowed them to more directly test the positivity effect as defined by Reed, Chan, and Mikels (2014). Upon a closer look at their results (Knight et al., 2002), older adults remembered positive and negative words equally well on an immediate recall test, revealing that there was no strong mood-congruent memory effect after all. On the delayed recall test, however, older adults seemed to show a negativity bias in the sad mood condition. It would be interesting to explore this in future work to see whether mood-congruent memory effects appear in older adults after longer test delays.

So overall there were no mood congruence effects observed, but what does this mean for the positivity effect in aging? Valence at baseline was the only self-reported measure that significantly correlated with the positivity of recall, but this was no longer significant when

controlling for age group (based on the regression analysis). Indeed, age group was the only significant predictor of positivity, because young adults frequently displayed a negativity bias whereas older adults did not. This supports the view that the positivity effect in aging is the result of a negativity bias that fades with age (Carstensen & DeLiema, 2018). Here, the negativity bias was consistent across all three mood conditions in young adults, and this shifted toward no negativity bias (or even a slight positivity preference) in older adults. This shift in emotional memory bias was further illustrated in the frequency distributions of the positivity of recall scores. However, these frequency distributions also showed that many young adults had a positivity bias and many older adults had a negativity bias. Although the general means might shift toward more positivity with age, many individual differences exist within each age group. In the present study, these differences were not explained by mood, nor were they explained by future time perspective, as would be predicted by Socioemotional Selectivity Theory (Carstensen & DeLiema, 2018; Reed et al., 2014).

In older adults, there also seemed to be a general “cost” to viewing an emotional video at the start of the experiment. Total picture recall was lower in older adults after viewing a positive video than after viewing a neutral video. Older adults have been shown to pay more attention to positive stimuli than to negative stimuli (Isaacowitz, Allard, et al., 2009). It is possible that they were more engaged and invested in the positive video (versus the negative video) while it was playing. This could have made it harder for them to disengage their attention and thoughts from the video after it stopped playing, to task switch and focus on the subsequent picture task. In light of the incidental encoding instructions, these older adults might have continued thinking about the positive video because they did not have to explicitly memorize or act on the pictures being shown. For the time being, this interpretation remains speculative until more work is done

using experimental mood manipulation in emotional memory tasks. These kinds of studies, especially ones in which item interrelatedness is controlled, have not been done until now. In addition, older adults who viewed a negative video later performed worse on a measure of general cognitive ability (i.e., MOCA) than those who had viewed a neutral video at the start of the experiment. This was despite them reporting similar levels of valence and arousal at the end of the experiment. Overall, in the present study, both emotional mood induction conditions seemed to incur a cognitive cost to older adults. Care should be taken when using mood induction techniques with older populations as these emotional manipulations could alter other cognitive functions.

### **Limitations**

One possible limitation in the present study was the relatively low recall scores, and consequently the limited range of scores in the memory task. This could have reduced our ability to detect meaningful interactions. The low scores and range could have resulted in large part from the use of incidental encoding instructions. We used an incidental memory task because the positivity effect seems stronger with this kind of task than with an intentional encoding task (see meta-analysis by Reed et al., 2014). We also did not want participants to make the connection between the video manipulation and picture memory task, which could have altered their recall. During debriefing, we verified that participants were unaware of the research hypotheses and link between the video and pictures. Because of the incidental task instructions, we included only 10 pictures per category (30 pictures total) to reduce possible floor effects. This is fewer than the 16 per category (64 pictures total) that we have used in previous work with young and older adults (Thesis Study 1). Future work should seek to use a memory task that could output higher

rates of recall and more of a range of scores to maximize the ability to detect meaningful statistical differences.

Another possible limitation in this and most other studies involves sampling or selection bias. In general, the most active and engaged older adults (i.e., those who voluntarily respond to study advertisements) are compared to university students—a young adult group who generally experience greater psychological distress than age-matched adults from the community (Adlaf et al., 2001). This may lead to the over-recruitment of the most positive older adults and the least positive young adults. Indeed, previous studies that recruited both young and older adults from the wider community reported no difference in positive affect (e.g., Charles et al., 2003; Grühn et al., 2007; Spaniol et al., 2008), and no positivity effect (e.g., Charles et al., 2003; Grühn et al., 2007; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Pruis, Neiss, Leigland, & Janowsky, 2009; Spaniol et al., 2008). Together, these observations suggest that there exist large differences in mood between young and older adults, which may be further exacerbated by sampling bias (see Thesis Study 4).

## **Conclusion**

In the present paper, young adults showed a persistent negative memory bias in all mood conditions. Yet, older adults showed no explicit positivity bias and recalled positive and negative pictures equally well. The mood manipulation somewhat affected participants' emotional memory and there was some indication of mood incongruence in both samples, which might serve to regulate emotions, especially in older adults. These results lend limited support for the mood-congruent hypothesis and socioemotional selectivity theory for the positivity effect in aging. Nonetheless, the robust age group differences in emotional memory show that a positivity

effect in aging can be understood as the reduction or complete elimination of the negativity bias that is commonly observed in young adults.

**Study 3. Do Mood and Time Perspective Predict Emotional Memory Bias? A Test of Mood  
Congruence and Socioemotional Selectivity Theory in Young Adults**

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### Abstract

Memory for emotional experiences changes with age. Young adults often remember negative information more often than positive information, whereas older adults seem to consistently remember positive more often than negative information. According to Socioemotional Selectivity Theory (SST), a positive memory bias in aging results from time perspective naturally changing with age, leading older adults to prioritize present-oriented goals such as emotional satisfaction. In the one experimental study of SST, Barber et al. (2016) showed that priming a present-oriented time perspective resulted in a positivity bias—in a sample mostly consistently of young adults. Yet, naturally-occurring differences in mood between young and older adults could have influenced part of these results. In an effort to dissociate the roles of mood and time perspective, we altered the priming task in Barber et al. (2016) to induce either a positive or negative mood, while inducing either a present or future time perspective, thus creating four conditions: present-positive, present-negative, future-positive, future-negative. A neutral time/mood condition and control condition (no written passage) were also included. Young adults ( $n = 156$ ) performed the written priming activity followed by an incidental free recall test of positive, negative, and neutral pictures (30 pictures total). Overall, the priming task did not greatly alter participants' self-reported mood or time perspective. In fact, young adults showed a strong negativity bias which persisted despite the mood and time manipulations. Time horizon and mood were not sufficient to explain the persistent negativity bias in the present study.

*Keywords:* emotion, memory, positivity effect, mood, time perspective, Socioemotional Selectivity Theory

## Introduction

As people's perception of time and life expectancy changes with age, so might their social goals and motivations and eventually, their memory (Carstensen & DeLiema, 2018; Carstensen et al., 1999; Charles et al., 2003). Young adults perceive time as vast, not limiting them to the present but allowing them to focus on expanding their horizons for the future, through exploration and learning (Socioemotional Selectivity Theory; SST). This might lead them to prioritize attending to and memorizing negative information, because it is arguably more valuable than positive information (Baumeister et al., 2001). On the other hand, older adults might perceive time as limited, leading to their dedicating more resources to fulfilling present-oriented goals such as increasing emotional meaning and satisfaction (Carstensen & DeLiema, 2018; Reed et al., 2014). This might lead older adults to prioritize processing positive information at the expense of negative information.

To my knowledge, there is only one study that has directly manipulated time perspective to measure its effects on emotional memory (i.e., Barber et al., 2016). In their two-part study, Barber et al. (2016) primed young and older adults to project their thoughts toward the future or the present. In the *present* condition, they read a text describing the fragility of life (e.g., "People can never know when life will end"; p. 880) and were asked to imagine that they had only 6 months more to live. In the *future* condition, they were encouraged to think of life as longer (e.g., "People keep living longer and longer [...] it is even possible that you might live to be 120"; p. 879) and to imagine living in good health until 120 years old. Participants were subsequently presented with positive and negative pictures (Experiments 1 and 2) as well as neutral pictures (Experiment 1) and given an immediate, self-paced free recall test. Overall, young and older adults recalled more positive than negative pictures when they were primed to think of the

present versus the future (Experiment 1). Their increased recall of positive images was also greater in the present-time condition when compared to a neutral-control condition (Experiment 2). These findings supported SST by showing that a limited view of time in which people focus on the present can increase one's memory for positive images. This was important in showing that inducing a present orientation in young adults, resulted in a positivity bias in their memory.

Although this novel technique studied more closely the foundations of SST, the results were somewhat contradictory upon closer examination. The results from Experiment 2 (in which 81% of participants were under 40 years old) did not parallel the results of young adults in Experiment 1. In Experiment 1 there was a strong negativity bias in the future condition but no emotional bias in the present condition, whereas in Experiment 2 there was a strong positivity bias in the present condition but no emotional bias in the future condition. Furthermore, it was unclear whether mood also affected the emotional memory biases, and as we point out in our previous work (Thesis Study 2B), this might be important to consider. In Barber et al. (2016), the strength of the association between the time manipulations and the positivity bias increased after controlling for mood, suggesting that mood suppressed, rather than mediated, the effects of time horizons on memory. But in fact, both mood and time horizons strongly predicted the positivity bias in Barber et al. (2016,  $\beta = .32$  for both factors in the regression analysis). Mood is an important factor to consider because of its vast effects on memory and cognition in general (for review, see Blaney, 1986; Bower, 1987; Eich et al., 2008). Of most relevance is mood-congruent theory which postulates that people who are in a positive mood will show a memory advantage for positive stimuli, and people who are in a negative mood will show a memory advantage for negative stimuli. The relationship between mood and time perspective and their respective influence on emotional memory remains unclear.

Mood and time perspective might play competing roles in memory because adopting a limited view of the future could a) increase emotion-oriented goals and produce a positivity bias (based on SST); or b) increase negative affect and produce a negativity bias (based on mood-congruent theory). It is possible that time perspective influences emotional memory to a certain extent, after which point mood congruence takes priority (e.g., when one's mood is more extreme or high in arousal). Together, these two opposing factors could explain the divergent findings of previous studies.

### **Current Study**

The goal of the current study was to examine the effects of mood and time perspective on emotional memory in young adults, to test predictions of mood congruence and SST, respectively. To this end, we adapted the time priming texts used by Barber et al. (2016) to include a manipulation of mood in addition to time. We also made a few adjustments to the memory task. We chose to use a standard emotional memory task which included an equal number of positive, negative, and neutral pictures (neutral pictures were completely absent in Experiment 2 and under sampled in Experiment 1 of Barber et al., 2016). The emotional pictures were matched in their level of arousal. The emotional and neutral pictures were matched in their level of semantic interrelatedness because this may explain part of emotion's enhancing effect on memory (Ferré, Fraga, Comesaña, & Sánchez-Casas, 2014; Talmi & McGarry, 2012), and is seldom controlled for in the positivity literature. Currently, SST predicts a significant positivity bias in participants who adopt a limited view of the future (i.e., those who are present-oriented), and a negativity bias in those who adopt an expansive view of the future (i.e., those who are future-oriented). Yet based on mood congruence, participants in a positive mood should display a positivity bias, and those in a negative mood should display a negativity bias. By manipulating

these two factors in young adults, we can understand how these factors influence emotional memory, and more specifically, the positivity bias. This allows us to evaluate the influence of mood and time perspective on positive memory biases, while eliminating possible age-related confounds that might alter these true effects (e.g., we are able to isolate the effects of reduced time perspective from that of increased age).

## Methods

### Participants

The final sample included 156 students (18-30 years old) from the University of Ottawa. Participants completed the study online so care was taken when screening the results. Forty-one students clicked through the entire survey without responding to any questions so they were automatically excluded. Data from incomplete sessions were also removed ( $n = 7$ ). One participant completed the study in full twice, so the second set of responses were removed. Some participants started the experiment twice ( $n = 21$ ), so their first set of incomplete responses were removed (they had completed on average 15% of the session during the first time through, this did not include the memory task). We also included a question at the end of the study asking participants to report any distractions or interruptions that may have occurred during the session. As a result, data were excluded from six participants who were in class while completing the study and from two people whose laptops died during the memory task which required them to complete it a second time. One other person was excluded because they were much older than the rest of the sample (40 years old). Participants completed a health questionnaire and were asked to self-disclose any emotional or psychiatric disorder. Fourteen people reported having depression, but this did not affect the results of the study so their data were retained in the reported analyses.

Students were recruited online through the University of Ottawa's undergraduate research pool and received course credit for their participation. They completed the study in English. Students were randomly assigned to one of the six conditions (control, neutral, present-positive, present-negative, future-positive, future-negative). Demographic and questionnaire data per condition are presented in Table 9. This project was approved by the local Research Ethics Board at the University of Ottawa (#H12-14-14).

Table 9

*Questionnaire Data by Condition*

	<b>Control</b>	<b>Neutral</b>	<b>Present-Positive</b>	<b>Present-Negative</b>	<b>Future-Positive</b>	<b>Future-Negative</b>
<i>n</i>	24	25	26	27	29	25
<i>Age</i>	19.17 (1.24)	19.12 (1.27)	19.73 (1.78)	19.44 (2.34)	19.66 (2.64)	19.32 (1.41)
<i>FTP-total</i>	44.04 (9.70)	48.68 (11.45)	48.81 (10.28)	48.81 (10.71)	45.72 (8.48)	45.04 (9.53)
<i>FTP-ambiguous</i>	15.96 (4.69)	17.4 (6.09)	14.15 (5.14)	17.11 (5.18)	14.14 (5.37)	16.36 (5.42)
<i>ERQ-appraisal</i>	12.92 (9.02)	16.96 (7.68)	18.69 (9.68)	14.48 (10.77)	18.28 (9.71)	19.20 (9.81)
<i>ERQ-suppression</i>	7.54 (5.93)	9.56 (5.87)	7.81 (4.76)	9.89 (6.37)	7.83 (5.54)	8.20 (5.80)

*Note.* Mean and SD for age (in years), Future Time Perspective total score (FTP-total), Future Time Perspective ambiguous subscore (FTP-ambiguous), Emotion Regulation Questionnaire cognitive appraisal component (ERQ-appraisal) and emotional suppression component (ERQ-suppression).

**Stimuli**

A set of 30 target images (10 positive, 10 negative, 10 neutral) and 4 buffer images (1 positive, 1 negative, 2 neutral) were used in this study (same as those from Thesis Study 2B).

The three types of pictures were matched in their level of semantic interrelatedness but differed

in their level of valence (see Table 10). The positive and negative pictures were equally arousing and more arousing than the neutral pictures.

Table 10

*Mean (SD) Ratings of Pictures*

	<b>Valence</b>	<b>Arousal</b>	<b>Semantic Interrelatedness</b>
<i>Positive</i>	2.96 (1.86)	4.67 (2.55)	3.99 (2.19)
<i>Negative</i>	7.68 (1.59)	4.56 (2.66)	3.88 (2.25)
<i>Neutral</i>	5.01 (1.16)	7.19 (2.11)	3.84 (2.08)

*Note.* Participants rated valence from 1 (happy) to 9 (unhappy) and arousal from 1 (excited) to 9 (calm), similar to P. J. Lang et al. (2008). The mean semantic interrelatedness of pairs of pictures was measured from 1 (not at all related) to 7 (extremely related), as per Talmi & McGarry (2012).

**Time x Mood Manipulation**

**Description of Priming Texts.** The manipulation procedures in this study are similar to those used in Barber et al. (2016), except the priming texts were modified to manipulate both time perspective and mood (rather than time perspective alone). There were six conditions in this study: control (no text), neutral time/neutral mood, present-positive, present-negative, future-positive, future-negative. In the control condition, no text was given to participants. The texts for the other five conditions can be found in Appendix B. In the neutral condition, participants read a text about the growth cycle of potatoes. This text was designed to elicit very little emotional response in participants. For the remaining four conditions that manipulated time and mood (present/future vs. positive/negative), each text started with a similar context that primed either the possibility of living to 120 (future conditions) or the idea that life can end unexpectedly (present conditions). The subsequent paragraph then described either a positive or negative

aspect of focusing on the future or the present, to manipulate mood. Each passage ended by telling people to answer the subsequent questions while either planning for a future in which they live until 120 (future conditions) or in which they only have 6 months to live (present conditions).

The texts for the five conditions were between 151 to 169 words in length. An online automatic readability calculator based on eight readability formulas was used to ensure similar level of difficulty across the texts (“Readability Formulas,” n.d.). The overall readability per passage was between grade levels 8 and 9.

**Pilot of Priming Texts.** We conducted an online pilot of 45 University of Ottawa students (27 women, 8 men) to evaluate the effectiveness of the texts in manipulating time and mood. In this pilot, we included two neutral texts (one about rubber and one about life expectancy), and four texts crossing present/future time perspective and positive/negative mood. Participants read both neutral texts and two of the other texts so that they were presented only one of each type of mood and time horizon (e.g., the two passages could have been the present-positive one and the future-negative one). Pilot participants read each passage and recorded their felt valence (unhappy to happy) and arousal (calm to excited) from 0 to 100 as well as the extent to which the text made them think of the past, present, and future (*not at all, a little, moderately, very much*). Overall, the neutral texts did not target the desired response. The passage on rubber made participants feel slightly more negative and the passage about life expectancy made them focus largely on the future. We therefore wrote another neutral passage about potato growth subsequent to the pilot to target more closely a true neutral response. This new text was reviewed in-house to ensure it elicited more of a neutral emotional response than did the original texts.

The other four texts generally elicited the desired emotional responses (Table 11). The positive texts were higher in valence (i.e., more positive) and higher in arousal than the negative texts. The texts also seemed to manipulate time horizons as expected. Participants thought more of the present after reading the present passages than after reading the future passages. Moreover, participants who read the future passages thought more of the future than of the present. A few improvements were made to the texts following these pilot results. First, we reinforced positive aspects of the present-positive text to encourage a higher valence response (which was around the neutral point on the scale, even if it was higher than what was reported for the negative texts). Second, we highlighted the present-oriented aspects of the present-negative text to further emphasize the time orientation in this passage. Overall, the pilot results were promising enough to warrant continuing with the full paradigm on memory.

Table 11

*Mean Ratings of the Four Priming Texts Manipulating Time Horizon and Mood*

	<b>Present-Positive</b>	<b>Present-Negative</b>	<b>Future-Positive</b>	<b>Future-Negative</b>
<i>n</i>	22	23	23	22
<i>Valence</i>	50.18	22.79	73.09	36.85
<i>Arousal</i>	57.05	37.00	55.83	39.25
<i>Past-oriented</i>	2.22	2.32	1.70	1.72
<i>Present-oriented</i>	3.41	3.57	2.65	2.59
<i>Future-oriented</i>	3.05	3.30	3.65	3.77

*Note.* Valence was rated from 0 (unhappy) to 100 (happy) and arousal was rated from 0 (calm) to 100 (excited). The past/present/future time orientations were measured from 1 (not at all) to 4 (very much).

**Priming Task.** Participants had 5 minutes to read the passage and write about how knowing this information would change their spending and savings plans, daily activities, life goals, and what they would do *if it were their last day to live* (present conditions) or *once they were a centenarian* (future conditions). They were given an additional 5 minutes if needed. Participants in the control condition were not asked to read an introductory text but were given similar questions to answer as participants in the priming conditions. Rather than speculate on what they would do if they had a shortened or extended life expectancy, control participants described their current spending habits, daily activities, and plans. The list of questions was identical to those used in Barber et al. (2016).

**Manipulation Check.** To check whether the texts induced the desired emotional state, participants reported their level of valence and arousal (Betella & Verschure, 2016) and completed the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) at baseline, after the priming task, and after the memory task. To check for changes in time perspective, participants indicated how far they felt they had progressed in their life, using a sliding scale from Barber et al. (2016). The scale anchors went from *start of life* to *end of life* and was coded 1 to 100. In using this scale in their pilot study, Barber et al. (2016) showed that participants in the future condition projected closer to the end of life than those in the present condition. As a second manipulation check for time perspective, all written responses were inputted into the Linguistic Inquiry and Word Count program (LIWC; Pennebaker, Booth, Boyd, & Francis, 2015). Thirty-eight categories (see Appendix C) were considered, including those that Barber et al. (2016) reported as significant, namely: social processes (family, friends), biological processes (health), drives (achievement), and personal concerns (work, home). Participants in the present condition should employ more social and positive emotional concepts whereas participants in the

future condition should employ concepts more related to personal concerns. The order of the mood check (affective sliders then PANAS) and the time perspective check (sliding scale and written responses) was randomized.

### **Procedures**

After giving their informed consent, participants began the experiment on E-Prime. At baseline, participants completed the affective sliders of valence and arousal and the PANAS, which were repeated again after the priming task and memory task. Participants then completed the priming task and manipulation check measures (for mood and time). The memory task began immediately after with an incidental encoding task, then an arithmetic task, and a free recall task. During the encoding task, participants were presented with a series of pictures one at a time (in random order) and told to view them as if they were watching a television. Each picture remained for 4 s followed by a blank screen for 500 ms. Two buffer images were shown at the start and end of the series of pictures to minimize the effects of primacy and recency. Once all pictures were presented, participants responded to simple arithmetic problems (involving addition, subtraction, multiplication, or division) by determining which of two equations produced a higher value (e.g., is it “7+4” or “6+6”). This ensured that performance reflected early long-term memory, by displacing items from working memory (Talmi et al., 2005). Immediately after, participants were given up to 10 minutes to type brief, yet informative, descriptions of the pictures they had seen during the encoding task. The primary author (KTAB) later scored each description as matching (i.e., correct recall) or not matching (i.e., ambiguous) one of the target images. All ambiguous descriptions were subsequently double checked. Participants also completed the Future Time Perspective (FTP) scale (from Carstensen & Lang, 1996) to obtain a total FTP score, and four additional future as ambiguous statements (from

Brothers, Chui, & Diehl, 2014) to measure ambiguous time orientation (FTP-ambiguous). Both scales required participants to indicate their agreement from 1 (very untrue) to 7 (very true) with a list of statements relating to different views of the future (future as open, limited, or ambiguous). Participants then completed the Emotion Regulation Questionnaire (Gross & John, 2003), measuring cognitive appraisal and emotion suppression. In addition, participants completed the Center for Epidemiologic Studies Depression scale (CES-D; Radloff, 1977), a demographics form, and health questionnaire. At the end of the tasks, participants were asked to report if they were distracted or interrupted while completing the online study, so we could make the necessary exclusions. A written debriefing form was provided at the end of the session and a funny dog video played at the very end to leave participants on a positive note.

### **Statistical Analyses**

We used SPSS Statistics 25 Software to conduct the analyses. The alpha value for all analyses was set to .05. A Bonferroni correction was applied to post hoc *t*-tests and the MANOVA of the LIWC values due to the large number of contrasts. A Huynh-Feldt correction was applied when sphericity was violated in a repeated measures analysis.

**Questionnaires on Time Horizons and Emotion Regulation.** Between-subject ANOVAs compared the six conditions (control, neutral, present-positive, present-negative, future-positive, future-negative) on the following dependent variables: FTP-total, FTP-ambiguous, ERQ-appraisal, ERQ-suppression. These variables assess traits that should not be influenced by the priming task. These analyses were conducted to ensure the randomly assigned groups did not differ significantly on these measures.

**Effect of Priming Task on Mood.** We conducted two mixed ANOVAs with self-reported valence and arousal, including the six Conditions as a between-subject factor and the

three Measurement Times (baseline, post-priming, post-memory task) as a within-subject factor. These mixed ANOVAs examined whether baseline emotional state was similar in the six conditions and whether differences emerged following the priming task or memory task. The same mixed ANOVAs design with Condition (6 levels) x Measurement Time (3 levels) was performed on the positive and negative PANAS scores. All significant effects in the ANOVAs were followed-up with post hoc *t*-tests.

**Effect of Priming Task on Time Perspective.** First, a univariate ANOVA compared the scores of life progression between the six conditions (control, neutral, present-positive, present-negative, future-positive, future-negative). Then, we analyzed the LIWC output variables. Barber et al. (2016) excluded written responses from the control condition because too few words were outputted. Along these lines, we performed a univariate ANOVA on total word count comparing the six conditions. Indeed, there were fewer words recalled in the control and neutral conditions so these were excluded from the subsequent analysis. A MANOVA compared the written responses on 37 LIWC dimensions with Time Horizon (present, future) and Mood (positive, negative) as between-subject factors. A Holm-Bonferroni correction was computed due to the large number of comparisons.

**Memory.** A mixed ANOVA with Condition (6 levels) and Picture Type (positive, negative, neutral) compared the rates of correct recall, and post hoc *t*-tests followed up on the significant effects. Crucially, these comparisons tested whether time horizons and/or mood influenced the positivity (or negativity) bias in young adults. To further examine the relationships between memory and the various mood and time perspective variables, we used Pearson's correlation to identify possible significant predictors of the positivity of recall to eventually input into a regression model. Positivity of recall was calculated as per Barber et al.

(2016) by subtracting the number of correctly recalled negative pictures from the number of correctly recalled positive pictures, then dividing the result by the total number of pictures recalled  $[(\text{positive} - \text{negative}) / (\text{positive} + \text{negative} + \text{neutral})]$ . We intended to input into the regression analysis positivity of recall as the dependent variable, with the following predictor variables: Condition (6 levels), valence (3 measurement times), arousal (3 measurement times), PANAS positive and negative affect (3 measurement times), life progression, FTP-Total, FTP-Ambiguous, ERQ-Appraisal, ERQ-Suppression, and self-disclosed depression.

## Results

### Data Screening

The data were normally distributed. Skewness and Kurtosis values were below 1 for all variables. There were a few outlying data points ( $n = 7$ ), but none of these were extreme outliers and no one person was an outlier on more than one variable. No variable had more than 2 outliers. We therefore retained all the data.

### Questionnaires on Time Horizons and Emotion Regulation

The six groups were matched in their age [ $F(5, 150) = .46, p = .809$ ], emotion regulation [appraisal:  $F(5, 150) = 1.72, p = .134$ ; and suppression:  $F(5, 150) = .79, p = .558$ ], and time horizons [total:  $F(5, 150) = 1.18, p = .321$ ; and ambiguous:  $F(5, 150) = 1.89, p = .100$ ].

### Manipulation Checks

**Mood.** The affective slider for valence revealed a main effect of Measurement Time [ $F(2, 290) = 20.50, p < .0001$ ] and an interaction between Condition x Measurement Time [ $F(10, 290) = 2.52, p = .008$ ; Huynh-Feldt correction applied], but no main effect of Condition [ $F(5, 145) = 1.43, p = .218$ ]. The main effect of Measurement Time resulted from participants reporting higher (positive) valence at baseline ( $M = 63.57$ ), lower valence after the priming task ( $M =$

60.01), and even lower valence after the memory task ( $M = 56.38$ ). To follow-up on the Condition x Measurement Time interaction, three univariate ANOVAs with Bonferroni post-hoc contrasts compared the six conditions at each time point individually. The main effect of Condition was significant at baseline [ $F(5, 149) = 2.65, p = .025$ ], but not after the priming task [ $F(5, 148) = 1.75, p = .126$ ] or after the memory task [ $F(5, 146) = 1.04, p = .398$ ]. At baseline (i.e., *before* the experimental manipulation), participants reported higher (positive) valence in the future-positive condition ( $M = 69.09$ ) than in the present-negative condition ( $M = 61.62; p = .044$ ). No other comparisons were significant. The arousal scores revealed no significant effect of Time [ $F(2, 269) = 1.32, p = .268$ ] or Condition [ $F(5, 136) = 1.32, p = .259$ ], and no interaction [ $F(10, 269) = 1.30, p = .231$ ; Huynh-Feldt correction applied to analyses]. The PANAS positive subscale revealed a main effect of Time [ $F(2, 292) = 19.42, p < .0001$ ; Huynh-Feldt correction applied]. Similar to self-reported valence, positive affect measured by the PANAS was highest at baseline ( $M = 24.71$ ), lower after the priming task ( $M = 23.66$ ), and lowest after the memory task ( $M = 21.97$ ), as confirmed by paired *t*-tests ( $ps \leq .007$ ). There was no main effect of Condition [ $F(5, 1505) = 1.57, p = .174$ ] or interaction [ $F(10, 293) = .98, p = .461$ ; Huynh-Feldt correction applied] for PANAS-positive. Similar results were found for PANAS-negative: a main effect of Time [ $F(2, 300) = 9.82, p < .0001$ ], but no main effect of Condition [ $F(5, 150) = 0.10, p = .992$ ] or interaction [ $F(10, 300) = 0.91, p = .522$ ]. Post-hoc paired *t*-tests revealed that negative affect decreased after the priming task ( $M = 16.84$ ) compared to baseline levels ( $M = 18.37; p < .0001$ ). Overall, the priming task did not seem to significantly alter participants' self-reported valence, arousal, positive affect, or negative affect.

**Time.** There was no significant effect of Condition on the life progression scale [ $F(5, 150) = 1.48, p = .198$ ], which was administered after the priming task. With regard to the written

output, there were significantly fewer words used in the neutral and control conditions compared to the other conditions [univariate ANOVA:  $F(5, 150) = 14.70$ , all  $ps < .0001$ ]. Similar to Barber et al. (2016), we did not consider these conditions in the subsequent analyses because there too few words to analyze. The MANOVA revealed a main effect of Time Horizon for the category *health* [ $F(1, 103) = 12.94$ , 1<sup>st</sup>-ranked  $p < .0001$ ]. Those in the future conditions spoke more about their health ( $M = 2.63$  words) than did those in the present conditions ( $M = 1.24$  words). There were no other significant effects after applying the Holm-Bonferroni correction.

### **Memory**

Data from seven participants were excluded because they did not follow the instructions and more than half of their picture descriptions were too ambiguous to score (excluded data were across all conditions except the control condition). The mixed ANOVA revealed a significant effect of Picture Type [ $F(2, 300) = 66.11$ ,  $p < .0001$ ]. Post-hoc paired  $t$ -tests showed that participants recalled more negative than positive pictures [ $t(155) = 3.45$ ,  $p = .001$ ], both of which they recalled more often than neutral pictures ( $ps < .0001$ ; Figure 6). There was no main effect of Condition [ $F(5, 150) = 0.61$ ,  $p = .700$ ] or interaction [ $F(10, 300) = 0.73$ ,  $p = .692$ ]. In addition, Condition and the various self-reported measures and questionnaires were not significantly correlated with positivity of recall scores. As such, no regression model was computed.

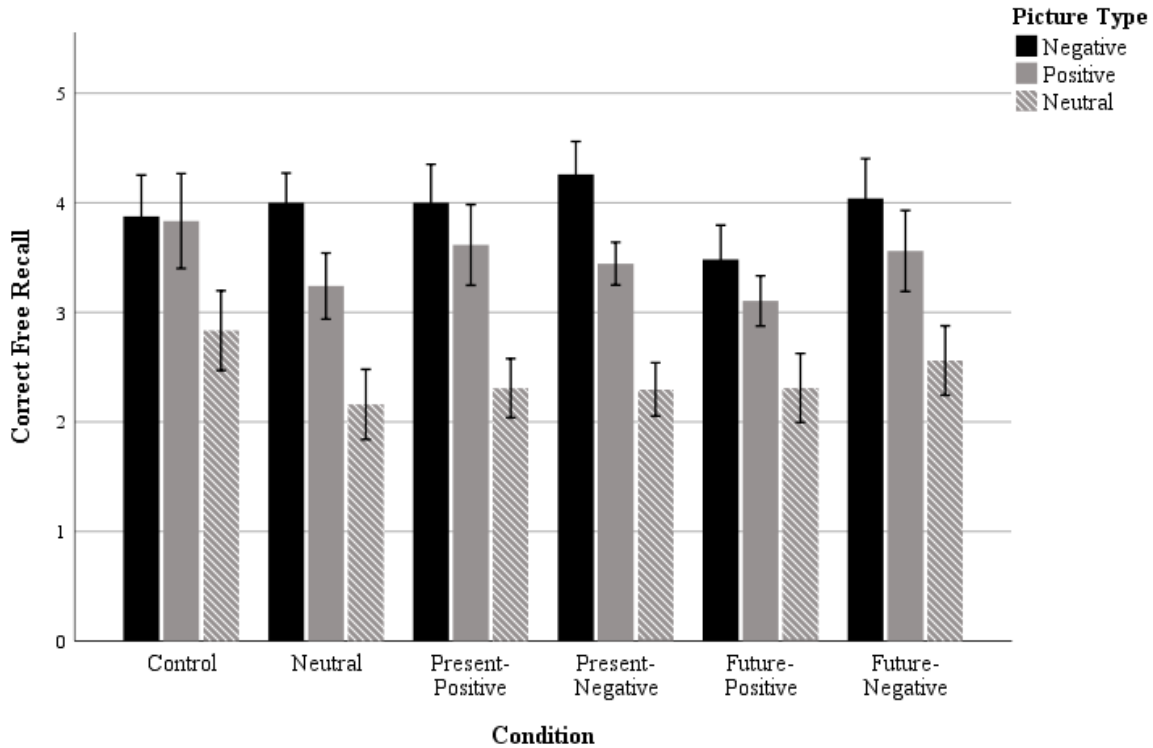


Figure 6. Correct recall of negative, positive, and neutral pictures by Condition.

## Discussion

In the present study, we sought to manipulate time perspective and mood within a single priming task to examine their influence on emotional memory biases. The purpose was to compare the predictions of Socioemotional Selectivity Theory with that of mood congruence. The priming task did not seem to greatly alter participants' self-reported valence, arousal, or positive/negative affect, but the time manipulation did influence participants' written output. Young adults showed the classic emotional enhancement of memory effect in which they recalled more emotional than neutral pictures. Of interest was their strong negativity bias, which persisted regardless of the priming condition.

Young adults clearly showed the classic emotional enhancement of memory effect. They recalled more emotional than neutral pictures in all conditions. Furthermore, their emotional memory was negatively biased in that they recalled more negative than positive pictures overall. This negativity bias was not significantly altered by the priming task and appeared in the majority of the conditions. This is in line with previous reports of the negativity bias being common in young adulthood (Baumeister et al., 2001; Carstensen & DeLiema, 2018; Reed et al., 2014). In fact, this negativity bias in young adults is argued to gradually fade throughout the lifespan, eventually leading to a positivity bias in older adults (Carstensen & DeLiema, 2018). This shift from a negativity bias to a positivity bias is commonly explained by a shift toward more present-oriented goals related to emotional satisfaction and meaningfulness. The results of the present study are unable to support this interpretation for a few reasons. First, participants in the future priming conditions wrote more about their health than did those in the present conditions (similar to Barber et al., 2016), suggesting a slight shift in their goals as they relate to the future. However, there was no subsequent change in memory. Second, time horizons—as measured by the Future Time Perspective scale (Carstensen & Lang, 1996)—did not correlate with participants' positivity of recall. Even if the priming effects were weak, we would still expect to find a significant relationship between self-reported time perspective and positivity of recall, given there was a sufficiently large range in scores for both measures. The Future Time Perspective scale has been used in previous studies on social goals and aging (e.g., F. R. Lang & Carstensen, 2002), but is rarely used to measure time perspective in studies on emotional memory. Because of the close link between time perspective and chronological age, it is important to measure both separately. Including a measure of time orientation in studies on emotional memory will serve as a useful tool to validate support for SST across studies.

In the current study, SST could not provide a sufficient account of the emotional memory bias in young adults, nor could mood-congruent theory. Memory did not change based on the mood condition (positive or negative), possibly due to the weak mood manipulation. The priming task did not seem to induce a significant change in mood from baseline levels. This could have been partially masked by the presence of baseline differences in valence between the future-positive and present-negative conditions (with the latter being more negative at baseline). Baseline differences in valence make it harder to induce and observe the desired changes. Moreover, there seemed to be a general trend of participants' valence and positive affect gradually decreasing throughout the course of the study, but also did their negative affect. This suggests that participants were gradually shifting toward a more neutral state. Once again, these trends were consistent across the positive and negative mood conditions. Induced or naturally-occurring shifts in emotional state were therefore unrelated to positivity of recall.

The generally weak manipulation effects of the priming task were surprising in light of the pilot results which showed large differences in valence and arousal across the mood conditions, and also differences in time perspective although this construct was measured differently than during the full memory protocol. One possible reason for these seemingly divergent findings could be that the pilot participants were rating the relative difference between the priming texts because they were exposed to four passages instead of just one. As a result, this could have artificially exaggerated the differences between the texts. Another consideration is the recruitment of online participants. When participants complete the study online, we had no direct way of measuring their adherence to the study instructions and priming task. The priming effects might be weaker if participants were less engaged, multitasking, or not reading the instructions. We attempted to minimize this by excluding any participant who reported they were

distracted during the study. However, some participants might not have reported the distractions. We note, however, that Barber et al. (2016) recruited participants for one of their studies online and still showed significant effects, so this is not a generalized finding for all online studies. Moreover, it would be important in future work to ensure that the texts also manipulate arousal. In the current study, the priming texts ended up inducing similar levels of self-reported arousal across conditions, including even the neutral and control conditions. This might explain in part why the emotional memory pattern was similar across conditions because the induced level of arousal was similar too. Arousal plays an important role in boosting memory (Kensinger & Schacter, 2006) and should be an important differentiating factor between neutral and emotional mood induction conditions in subsequent manipulations.

### **Conclusion**

The current study discusses the importance of dissociating the influences of time perspective and mood on emotional memory bias. Based on the current findings, we were unable to determine the relative strength of mood and time perspective in predicting positivity of recall in young adults; neither factor strongly influenced memory. Young adults showed a persistent negativity bias across all conditions. This emotional memory bias was not explained in terms of self-reported measures of emotional state or time horizons, suggesting that additional factors outside of mood-congruent theory and Socioemotional Selectivity Theory influenced memory.

**Study 4. Recruitment Matters: How Young Adult Sampling Might Affect Emotion-Enhanced Memory**

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### Abstract

People often remember emotional information, especially the negative kind, more often than neutral information. This has often been reported in university students, yet a negative memory bias might not be as prevalent in adults from the general community. Students experience more stress and emotional disruptions than community-dwelling adults of a similar age. These differences, among others, may contribute to altered memory and emotion processing in students compared to non-student adults. In the present study, 32 students (mean age = 19.84 years) and 27 non-students (mean age = 24.85 years) from Ottawa completed a number of questionnaires and a free recall emotional memory picture task. Overall, the students were younger in age, had fewer years of education, and adopted a more ambiguous time perspective (Brothers et al., 2014) than the non-students. The two groups did not differ in their level of positive or negative affect (Watson et al., 1988), depressive symptoms (Radloff, 1977), self-reported emotion regulation (Gross & John, 2003), or future time perspective (Carstensen & Lang, 1996). Importantly, the two groups differed in their emotional memory. Whereas students remembered both negative and positive pictures more often than (semantically-related) neutral pictures, non-students remembered positive—but not negative—pictures better than (semantically-related) neutral pictures. Therefore, students showed a negativity preference but this was absent in non-students. These results highlight the importance of including non-student samples in studies on emotional memory. We discuss the implications of these findings for research on the positivity effect in aging, which may be especially sensitive to student recruitment practices.

*Keywords:* emotional memory, recruitment bias, positivity effect, non-student adults

## Introduction

Experimental psychology relies heavily on undergraduate research pools in large part because of convenience. The seemingly unlimited availability of undergraduate students can help research advance faster, but may also reduce the generalizability of findings to the wider public. Post-secondary students and non-student adults of similar age differ in many ways, which may alter the way they think and feel.

In many countries, university studies are a source of countless major stressors (Steptoe, Tsuda, Tanaka, & Wardle, 2007). Students from various fields experience elevated stress (Robotham & Julian, 2006) and psychology students are no exception (Hughes, 2005). They must manage examinations, financial obligations, career choices, altered sleep and eating habits, and the list continues (Robotham, 2008; Robotham & Julian, 2006). These various stressors can cause a number of emotional and behavioural disruptions in students' lives (Misra, McKean, West, & Russo, 2000). Of great concern is the higher prevalence of psychological distress (Adlaf et al., 2001; Stallman, 2008, 2010) and depression (Ibrahim, Kelly, Adams, & Glazebrook, 2013) in university students compared to non-student adults. These behavioural and psychological differences between students and non-students may conceivably alter cognitive functions, such as memory.

Moderate stress can benefit memory, but the chronic and acute stress induced by university studies may also impair memory. Indeed, high or maintained stress can impair the different stages of episodic memory formation (Sandi, 2013; Shields, Sazma, McCullough, & Yonelinas, 2017). This may result from long-term changes in brain regions associated with memory and emotion (e.g., amygdala, hippocampus, prefrontal cortex; Roozendaal, McEwen, & Chattarji, 2009; Sandi, 2013). Students are often exposed to acute and/or chronic stress, which

may alter or even impair their memory relative to non-student adults. Depressive symptoms in students may further exacerbate memory deficits because of depression's adverse effects on memory (Marazziti, Consoli, Picchetti, Carlini, & Faravelli, 2010).

Given these differences between students and non-students, there may also exist differences in their emotional memory. Oftentimes, young adults will remember negative information more easily than positive or neutral information (i.e., they demonstrate a *negative memory bias*). Stress selectively enhances memory for emotional (versus neutral) information, providing a particular advantage to negative material (Sandi, 2013). In depression, positive information is more easily forgotten than negative information (Besche-Richard, 2013), perhaps due to disrupted long-term potentiation in the hippocampus (Dillon, 2015). Even in healthy adults, increased negative affect is associated with greater memory for negative material versus positive or neutral material. According to mood-congruent theory, adults demonstrate an emotional memory bias for material that is congruent with one's current mood (Eich et al., 2008). Therefore, if students and non-students differ in their moods, this may also lead to differences in their emotional memory.

In the present paper, we examined whether students and non-students differ in their positive and negative affect, depressive symptoms, self-reported emotion regulation, and time perspective and whether they would demonstrate a divergent pattern of emotional memory. We expected students to report higher levels of negative affect and more depressive symptoms than non-students. Furthermore, we expected students to display a large negative memory bias and for non-students to display a smaller, or even opposite (i.e., positive) memory bias. We believed that previous reports of a negativity bias in young adults (primarily student samples) could be attributed in part to students' increased negative affect and depressive symptoms. We minimized

the potential confounding effects of semantic relatedness on memory (Ack Baraly et al., 2019; Talmi, 2013) by including two sets of neutral stimuli: one set that was as highly interrelated as the emotional stimuli and another that was lower in interrelatedness. We further tested whether students would demonstrate reduced emotion regulation and altered time perspective compared to non-students, given the importance of these factors in age-related emotional memory biases (Charles et al., 2003; Reed & Carstensen, 2012; Reed et al., 2014).

## Methods

### Participants

Participants were between 18 to 35 years old and were either undergraduate students at the University of Ottawa (*student group*) or residents of the city of Ottawa (*non-student group*). A total of 32 students and 27 non-students participated in the study (see Table 12 for demographic information). Based on a power analysis performed a priori with G\*Power 3.1 software (Faul et al., 2009), a sample of 25 participants per group should yield .80 power for detecting a small-to-medium interaction between participant Group and Picture Type (2 groups, 4 repeated measures, repeated measures correlation = .6<sup>20</sup>, effect size  $f = 0.15$ ; power = .80).

The student group was recruited exclusively through the School of Psychology's undergraduate student pool whereas the non-student group was recruited through flyers posted online and in community centres and groups throughout the city. The non-student group was comprised solely of individuals who were not currently studying, in part- or in full-time, at any post-secondary institution (this also excludes students who were on summer break). For their participation, the university students received course credit and the non-students received \$10.

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<sup>20</sup> Value based on the data from Thesis Study 1 (Ack Baraly, Morand, Fusca, Davidson, & Hot, 2019).

All provided written informed consent and completed the tasks in their choice of English or French. Data from two students were removed because one reported having a psychiatric disorder affecting memory and another was an extreme outlier on the PANAS-Negative scale. Data from one non-student adult were excluded because of current substance dependence. This study was approved by the University of Ottawa Research Ethics Board (#H12-14-14).

Table 12

*Questionnaire Data for Students vs. Non-Students*

	<b>Students</b>	<b>Non-students</b>	<b>t-test</b>
<i>n</i>	32 (18 Males)	27 (6 Males)	
<i>*Age</i>	19.84 (2.41)	24.85 (3.00)	$t = 7.11, p < .0001$
<i>*Education</i>	13.06 (1.37)	16.19 (1.76)	$t = 7.68, p < .0001$
<i>CES-D</i>	14.63 (8.76)	11.04 (7.57)	$t = 1.67, p = .099$
<i>PANAS-positive</i>	30.77 (8.05)	29.41 (8.32)	$t = 0.64, p = .528$
<i>PANAS-negative</i>	14.71 (3.97)	15.00 (6.82)	$t = 0.19, p = .847$
<i>ERQ-appraisal</i>	29.61 (5.75)	29.41 (6.76)	$t = 0.12, p = .906$
<i>ERQ-suppression</i>	15.71 (4.33)	13.67 (5.41)	$t = 1.55, p = .126$
<i>FTP-total</i>	49.93 (8.44)	54.19 (9.38)	$t = 1.75, p = .085$
<i>*FTP-ambiguous</i>	16.56 (5.17)	13.85 (4.29)	$t = 2.09, p = .041$

*Note.* Mean and SD for age (in years), education (in years), Centre for Epidemiologic Studies Depression scale (CES-D); Positive and Negative Affect Schedule (PANAS); Emotion Regulation Questionnaire (ERQ); Future Time Perspective (FTP) scales. \*Student vs. non-student differences significant at  $p < .05$ .

## Stimuli

The target images consisted of 16 positive, 16 negative, 16 related-neutral and 16 unrelated-neutral pictures, depicting scenes of people, objects, animals, homes, or landscapes. An additional 16 pictures (4 per category) were chosen as buffer images to minimize the effects of primacy and recency on memory. The related-neutral pictures depicted domestic scenes of people, objects, or landscapes around the house (e.g., man painting a room, ironing board, or backyard), whereas the unrelated-neutral pictures had no obvious thematic link (e.g., blue mug, buffalo, or outdoor staircase). These pictures were piloted and previously used in a separate experiment, where we provided ratings of emotional valence, arousal, and semantic inter-relatedness (Table 13; Thesis Study 1; Ack Baraly et al., 2019). Overall, the negative and positive pictures are more arousing and of different valences than the neutral pictures which are themselves matched on both dimensions. Additionally, the negative, positive, and related-neutral pictures are more highly interrelated than the unrelated-neutral pictures (for ratings procedures and statistical results, see Ack Baraly et al., 2019).

Table 13

*Mean (SD) Valence, Arousal, and Interrelatedness Ratings for Each Picture Type*

	<b>Negative</b>	<b>Positive</b>	<b>Related-neutral</b>	<b>Unrelated-neutral</b>
<i>Valence</i>	7.77 (0.57)	2.10 (0.41)	4.65 (0.58)	4.68 (0.78)
<i>Arousal</i>	2.72 (0.75)	3.48 (1.07)	5.86 (0.49)	5.49 (0.69)
<i>Interrelatedness</i>	3.97 (1.14)	3.70 (0.87)	4.15 (1.25)	2.24 (0.83)

*Note.* Valence was rated from 1 (happy) to 9 (unhappy), arousal from 1 (excited) to 9 (calm), and relatedness from 1 (not at all related) to 7 (extremely related). Ratings procedures and statistics reported in Ack Baraly et al. (2019).

## Procedures

The memory task consisted of three parts: intentional encoding, 1-minute distraction task, and free recall. During encoding, participants viewed pictures one at a time in random order. Each picture appeared for 2 s, followed by a blank screen for 4 s. Participants saw a total of 20 pictures in each block (4 blocks total, each including 16 targets and 4 buffers). After viewing one block of pictures, participants completed a 1-minute distraction task consisting of short arithmetic calculations involving addition, subtraction, multiplication, or division (e.g., which equation produces the higher value “15+39” or “25+18”?). This distraction task helped displace items from working memory so that the free recall test measured primarily long-term memory (Talmi et al., 2005). After the distraction task, participants had 3 minutes to describe out loud as many of the pictures as they could remember from the current block. The experimenter wrote down their responses and audio-recorded the session for later verification. If a description was unclear, the experimenter asked the participant for additional details. Once free recall was over, the next block of pictures began. Participants completed a practice at the start of the experiment to familiarize themselves with the procedures. The memory task ran on E-Prime 2.0 software.

Subsequently, participants filled out a demographics and health questionnaire, the Centre for Epidemiologic Studies Depression scale (CES-D; Radloff, 1977), the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988), the Emotion Regulation Questionnaire (Gross & John, 2003), and the Future Time Perspective (FTP) scales (Brothers et al., 2014; Carstensen & Lang, 1996). The CES-D is a 20-item scale measuring depressive symptomatology over the past week. The PANAS includes 20 words describing feelings and measures current positive and negative affect. The ERQ consists of 10 statements used to measure two facets of emotion regulation: cognitive reappraisal and expressive suppression. We calculated two scores for time

perspective. The FTP-total score includes 10 statements (Carstensen & Lang, 1996) that measure one's propensity to view the future as expansive or unlimited. The FTP-ambiguous score includes four statements (Brothers et al., 2014) that measure one's propensity to view the future as ambiguous. In total, the study took one hour to complete.

### **Statistical Analyses**

Each picture description was correct if the rater could easily match it to one of the target pictures. No point was given if participants recalled pictures from previous study blocks (i.e., they had to recall them during the free recall immediately subsequent to their encoding). The experimenter (SA or KTAB) scored the picture descriptions during recall to ensure accuracy in the scoring and a second rater (SA or KTAB) subsequently double checked the scoring. Less than 1% of descriptions were too ambiguous to score.

Group differences on the self-reported questionnaires were compared using independent samples *t*-tests. The data were then subject to a 2 x 4 repeated measures ANCOVA with Group (student, non-student) as the between-subjects factor and Picture Type (negative, positive, related neutral, unrelated neutral) as the within-subjects factors, with total correct recall as the dependent variable. Alpha was set to .05, except post hoc analyses which used Bonferroni-corrected alpha. Analyses were performed using SPSS Statistics 25 software.

### **Results**

Prior to running the analyses, we ensured that the data were normally distributed based on the Kurtosis and Skewness values calculated in SPSS. Table 12 shows that the students were younger in age, had completed fewer years of education, and viewed their future as more ambiguous than non-students. These three variables were included as covariates in the

subsequent ANCOVA. The student and non-student groups did not differ in the remaining variables (see Table 12).

The ANCOVA revealed a significant main effect of Picture Type [ $F(3,147) = 4.39, p = .005, \eta_p^2 = .082$ ] and two interactions: Picture Type x Education [ $F(3,147) = 3.01, p = .032, \eta_p^2 = .058$ ] and Group x Picture Type [ $F(3,147) = 3.08, p = .029, \eta_p^2 = .059$ ; see Figure 7]. There was no main effect of Group, Education, Age, or Ambiguous Time Perspective and none of the remaining interactions were significant (all  $ps > .100$ ). First, we found that years of education was significantly and positively correlated with recall of unrelated-neutral pictures in non-students ( $r = .529, p = .005$ ), but not in students ( $r = .149, p = .415$ ), elucidating part of the Group x Picture Type interaction (Figure 8). We then conducted post hoc  $t$ -tests (using a Bonferroni-corrected alpha of  $.05/12 = .004$ ) to further investigate the Group x Picture Type interaction and to test our main hypotheses. Students showed the classic EEM effect: They recalled positive and negative pictures better than related-neutral pictures and unrelated-neutral pictures [ $t(31) > 5.00, ps < .0001$ ]. Their recall of positive and negative pictures did not differ [ $t(31) = .230, p = .820$ ], nor did their recall of related-neutral and unrelated-neutral pictures after Bonferroni correction [ $t(31) = 2.822, p = .008$ ]. This EEM effect (negative = positive > related-neutral) was not reproduced in the non-student group. Non-students recalled positive pictures more often than related-neutral pictures [ $t(26) = 4.42, p < .0001$ ], but they did not recall negative pictures more often than positive pictures [ $t(26) = 1.80, p = .083$ ] or related-neutral pictures [ $t(26) = 2.51, p = .019$ ]. Non-students also recalled unrelated-neutral pictures less often than all other types of pictures ( $ps \leq .003$ ). Therefore, students recalled both positive and negative pictures more often than the related-neutral pictures, but the non-students only recalled the positive pictures better than the related-neutral ones.

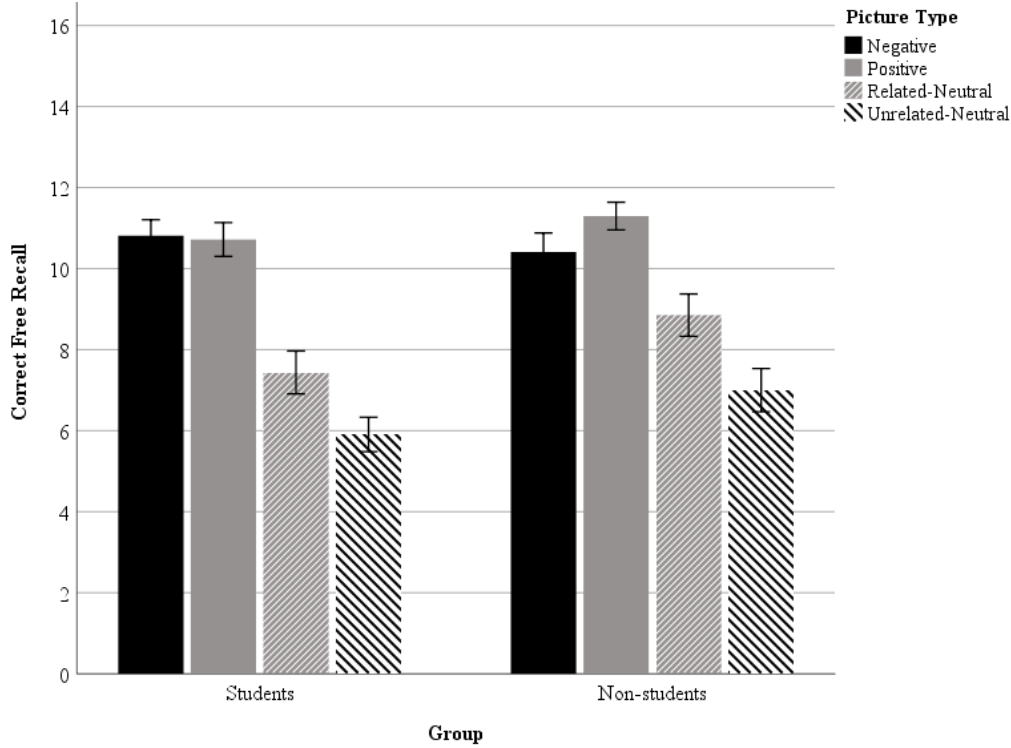


Figure 7. Mean correct recall for each picture type by group. Error bars represent one standard error of the mean.

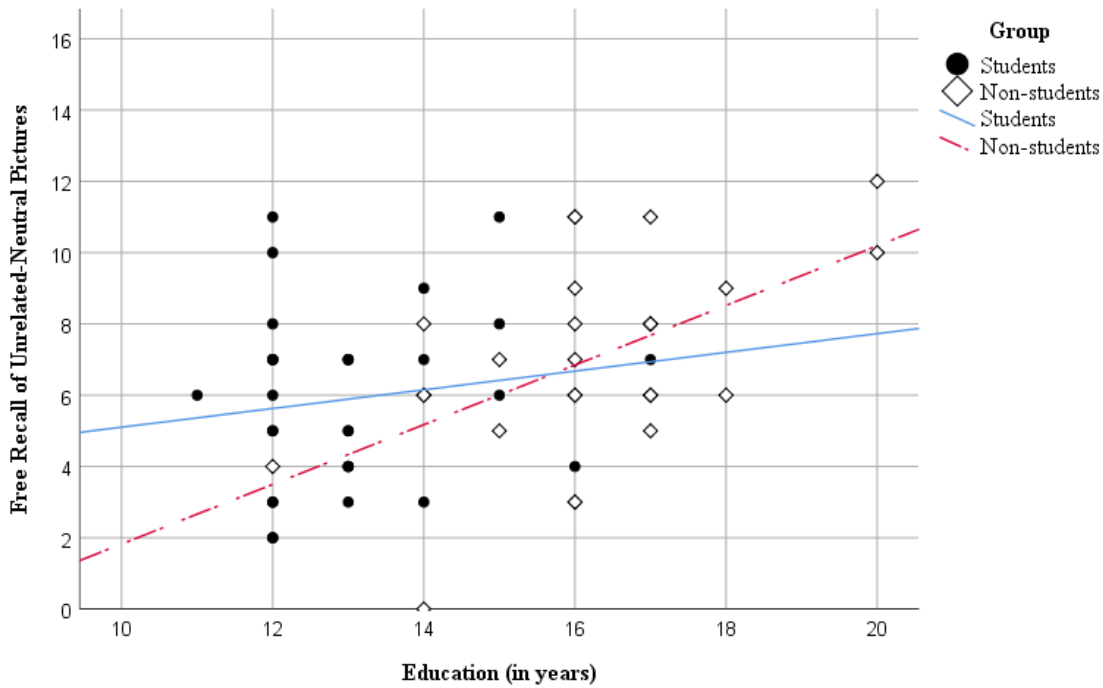


Figure 8. Correlation between participants' years of education and correct recall of unrelated-neutral pictures by group (students vs. non-students).

## Discussion

The purpose of this study was to examine whether young adult students and non-students differ in their emotion processing and memory. Indeed, students and non-students differed in their time perspective and emotional memory bias, but they did not significantly differ in their reported levels of affect, depressive symptoms, or self-reported emotion regulation. Not surprisingly, students viewed their future as more ambiguous than non-students. Non-students also displayed a positive memory advantage over related-neutral pictures that did not appear for negative pictures. In contrast, students remembered both negative and positive pictures more often than related-neutral pictures and showed no advantage of one emotion over the other. These findings highlight possible cognitive differences that exist between young adults who are university students and those who are not.

### Students Can Differ from Non-Students

Students and non-students responded similarly on the questionnaires evaluating affect, depressive symptoms, and self-reported emotion regulation. This was contrary to our prediction that students would report higher levels of negative affect and depressive symptoms and reduced emotion regulation compared to non-students. The mean responses on most questionnaires was nearly identical for both groups and the standard deviations were generally large. Students may have reported more symptoms of depression than non-students, but this effect was toward trend ( $p = .099$ ) and variance was also high. There were however, marked differences in time perspective between students and non-students. Students viewed their futures as more ambiguous than non-students, a finding likely attributed to the temporary nature of university studies and uncertain job/career prospects. However, this difference in time perspective did not affect memory. On the other hand, years of education did: Non-students with more formal education

remembered more unrelated-neutral pictures. This appeared to be an isolated effect because education did not significantly correlate with memory for the other types of pictures. Overall, students and non-students responded similarly on many of the dimensions assessed, with the exception of their time perspective and possibly depressive symptomatology. We chose to measure affect and depressive symptoms to test mood-congruent theory (Eich et al., 2008), and self-reported emotion regulation and time perspective to test Socioemotional Selectivity Theory (Carstensen et al., 1999; Charles et al., 2003; Reed et al., 2014), but students and non-students may also have differed in many other important ways. Future studies could include direct measures of psychological distress, anxiety, sleep habits, or other factors that may be affected by university studies and also influence memory.

Students and non-students also performed differently on the emotional memory task: Students showed evidence of a negativity and positivity preference (over neutral material) but no negativity preference was found in non-students. Students remembered both positive and negative pictures better than neutral ones. In contrast, non-students remembered more positive than related-neutral pictures, but they did not remember negative pictures more often than related-neutral pictures. Descriptively, non-students even appeared to remember more positive than negative pictures, but this did not reach statistical significance ( $p = .083$ ). Although there was no sign of a negativity bias in students, these results still align with the prediction that non-students' memory is more positively biased—and less negatively biased—than that of students. These results parallel findings from our previous work that used the exact same stimuli and methods (Ack Baraly et al., 2019, Exp. 2). In both studies, university students displayed no memory bias toward positive or negative emotion. In contrast, non-student young adults (current study) and older adults (Ack Baraly et al., 2019, Exp. 2) displayed an emotional memory

advantage specifically for positive pictures. This questions the extent to which previous reports of a negativity bias in students generalizes to non-student young adults and whether the positivity bias commonly observed in older adults is specific to aging or results in part from improperly matched age groups.

### **Recruitment Practices in Aging Studies**

Most studies on the positivity effect in aging compare older adults to young adult students. Yet, students may not be the most suitable control group for older adults. First, students' results may not generalize to all young adults. As reported in the present paper, students' emotional memory may not always reflect that of young adults in general. In aging research, older adults' results are often interpreted in comparison to younger adults. Therefore, the particular young adult sample used as the reference group for the age comparison is crucial to the interpretation of results. If students' memory is more negatively biased than non-students' memory, then this would further exaggerate the relative "positivity" of older adults' emotional memory. Comparing the results of the present study to that of our previous work (Ack Baraly et al., 2019), it would appear that the non-students did indeed perform more similarly to older adults on the memory task than to students who were closer in age. Moreover, a common explanation of the positivity bias in aging is based on differences in time perspective between young and older adults (Socioemotional Selectivity Theory; Carstensen & DeLiema, 2018; Carstensen et al., 1999; Reed et al., 2014). Yet, as observed in the current paper, differences in time perspective may exist between students and non-students. The extent to which young adult sampling affects the relative positivity bias in older adults needs to be explored more closely in future work.

A second major concern in recruiting predominantly students is the use of vastly different recruitment practices which could lead to systematic age-group differences unattributable to chronological age. Older adults are typically recruited through means of flyer and newspaper advertisements in the general community, whereas students typically sign-up through undergraduate recruitment pools to receive course credit. Although motivation was not measured in the current study, it is reasonable to assume that non-students and older adults would be more motivated to participate in research than would be students. They must invest more time to participate in a study (i.e., time required to respond to the advertisement, schedule a session, physically travel to and locate the laboratory, etc.) and may be more attentive and follow instructions more closely than students who often participate just for the course credit. A better control for aging research would therefore be non-student young adults from the same community. This would minimize the impact of uncontrollable factors inherent in different recruitment practices.

## **Conclusion**

It is common practice to recruit young adult participants from undergraduate research pools; it is a time-effective and inexpensive mean to fulfilling recruitment needs. Yet, students may differ from non-student young adults in many important ways. In the present study, students showed a negativity preference in memory that was not found in non-students who only showed a positivity preference. Furthermore, the two groups reported differences in their time perspective, with students adopting a more ambiguous view of the future than non-students. These are but two ways in which students may differ from non-student adults in their cognitive function. The generalizability of findings on emotional memory may be limited, highlighting possible limitations of using university students as reference groups in aging studies.

**CHAPTER 3. DISCUSSION AND CONCLUSION**

Many aspects of memory may change or decline with age, but not all changes are negative. Some might even be positive. This seems to be the case in memory for emotional information. Whereas young adults tend to remember negative information more often than positive information, older adults usually show the opposite effect (Carstensen & DeLiema, 2018; Reed et al., 2014). Over the past decade, researchers have conducted over 70 experiments trying to characterize this positivity effect in aging memory. Yet, very few of them account for the basic interactions that exist between memory and emotion, factors partially independent of aging which could explain some of the existing controversy in the literature. This thesis examined the fundamental cognitive mechanisms supporting emotional memory in older adults to explain *how* a positivity bias is produced. Then, I explored *why* this bias might appear selectively in older adults by considering the effects of mood. In light of the prevalence of dementia and memory disorders in the aging population, it has become ever more important to understand how and why these changes occur in normal aging, to eventually dissociate them from changes linked to underlying pathologies.

In this work, I show that two extrinsic factors (item interrelatedness and distinctiveness) are fundamental to producing a positivity bias in healthy older adults. However, this positive memory bias cannot be fully explained by the intrinsic factor, mood. Manipulating mood had minimal influence on the negativity bias in young adults, and only slightly influenced memory for positive information (vs. neutral information) in older adults. In my final study, I show that university students might not always match young adults from the community in their pattern of emotional memory bias, thus questioning their use as a young-adult reference group in aging studies. This, in addition to other useful methodological considerations are highlighted at the end

of this thesis. These will help researchers with their experimental designs, to better characterize changes in emotional memory that are normal in aging.

### **Summary of Findings**

There are two consistent observations in all of my thesis studies. The first is that emotion improves memory in young and older adults. The second, is that young and older adults differ in their emotional memory bias—whether it be toward positive or negative stimuli. In general, memory was more positively biased in older adults and more negatively biased in young adults, but this varied somewhat by experiment. There was one clear exception: Young adults recruited from the wider community showed a slight preference for positive stimuli. Their positivity preference was more similar to what was seen in older adults than to their university student counterparts. The results of each study are summarized in Table 14.

### **Inconsistency in Emotional Memory Bias**

The positivity bias in older adults and the negativity bias in young adults were inconsistent across studies. Older adults showed a memory advantage for positive over negative stimuli in one study (Study 1, Experiment 2) but not in the other (Study 2B) in which only a preference for positive over neutral stimuli was observed. In Study 2B, an incidental encoding task was used to encourage an unconstrained and naturalistic processing of stimuli, which may be more likely to reveal a positivity bias in older adults (Reed et al., 2014). We employed the same task instructions found in the Reed et al. (2014) meta-analysis (i.e., “instructing participants to view images as they would a TV”, p. 2), and yet, older adults showed no memory advantage for positive over negative stimuli in this experiment. Despite using incidental encoding instructions, it is possible that the mood manipulation otherwise constrained

Table 14

*Summary of Thesis Results and Conclusions*

Study	Factors	Encoding	Young Adult (YA) Results	Older Adult (OA) Results	Conclusion	Theoretical implications
1	Semantic relatedness and distinctiveness	Intentional	General EEM: No negativity bias (neg = pos > neut).	Positivity bias (pos > neg) in mixed lists but not in unmixed lists.	Relatedness and distinctiveness influence emotional memory in OA.  Relatedness influences emotional memory in YA.	Support for mediation theory in OA, partial support in YA.
2A	Video ratings	-----	-----	-----	6 videos chosen for Study 2B (2 positive, 2 negative, 2 neutral).	-----
2B	Mood induction	Incidental	Negativity bias (neg > pos) in all conditions; strongest in the positive mood condition.	Slight positivity preference (pos > neut) in the negative mood condition.	Mood had a slight influence on the positivity preference in OA. Some evidence of mood-incongruent memory.	No support for the mood-congruent hypothesis. Possible explanation by the Affect Infusion Model.
3	Mood and Time priming	Incidental	Negativity bias (totalled across all conditions).	-----	Persistent negativity bias despite mood/time manipulation.	No support for theories of mood congruence or SST.
4	Mood and young adult sampling	Intentional	Non-students: Positivity preference (pos > neut).  Students: General EEM.	-----	Emotional memory different in both samples.	Non-students' memory more similar to OA (Study 2B) than to YA.

*Note.* YA = Young adult; OA = Older adult; EEM = Emotion-Enhanced Memory; SST = Socioemotional Selectivity Theory.

older adults' processing of stimuli. They might not have processed the emotional stimuli as they would have naturally because their emotional states were experimentally altered, thus reducing their naturalistic processing of the pictures. Of course, the purpose of the experiment was to manipulate their information processing to bias them toward positive or negative stimuli, but in doing so, their natural bias toward positive stimuli might have been reduced even in conditions of neutral or positive mood manipulation. This could further explain why they did not show a positivity bias in the neutral video condition, because this is not identical to how older adults would process information in the absence of any experimental video manipulation.

Similarly, the negativity bias in young adults was also inconsistent. In half of the studies, young adults showed a memory advantage for negative over positive stimuli, but in the other half of studies their recall was similar. In all studies, however, they did show evidence of a negativity preference, because their memory was consistently better for negative than for neutral stimuli (with the exception of non-student young adults, discussed hereafter). The inconsistency of their negativity bias is surprising, given that Reed et al. (2014) found it to be robust in many experimental designs considered in their meta-analysis. In the present studies, young adults' negativity bias only appeared in the studies using incidental encoding and not in those using intentional encoding instructions. It is possible then, that as with the aging positivity bias, young adults' negativity bias is stronger when their processing of stimuli is not constrained by explicit task instructions (e.g., intentional encoding), which would promote their natural negativity bias to occur (Reed et al., 2014). By constraining processing in an intentional encoding task, young adults' potential motivation to prioritize negative information (Carstensen et al., 1999; Reed et al., 2014) is potentially weakened in their effort to perform optimally in the task at hand by remembering the most amount of pictures from all categories.

### **Experimental Manipulations Affected Older Adults but not Young Adults**

Patterns of emotion-enhanced memory in young adults were not affected by any of the experimental manipulations that affected memory in older adults. Older adults' positivity bias was altered by manipulating cognitive factors (Study 1) and their positivity preference was slightly altered by manipulating mood (Study 2B). On the other hand, young adults' emotion-enhanced memory and negativity bias were not altered by manipulating cognitive factors or mood. Their negativity bias was evident in all video mood conditions and when totaling recall across all mood and time conditions in the priming task (Study 3). Although their negativity bias was inconsistent across studies, the fact that their emotional memory was unaffected by the manipulations supports the view that their memory patterns are robust in a variety of experimental designs and protocols (Reed et al., 2014). This may be less true of the positivity bias in older adults, which remains controversial in the literature (Grühn et al., 2016; Kan et al., 2018).

### **A Positivity Bias or a Positivity Effect?**

Emotion can interact with memory in many ways. This can make it challenging when describing patterns of emotion-enhanced memory in aging. At the start of this thesis, I differentiated the ways in which we could define some of these patterns. A *positivity preference* is a memory advantage for positive over neutral information; a *positivity bias* is a memory advantage for positive over negative information; and a *positivity effect* is a memory advantage for positive over negative information (i.e., a positivity bias) that is larger in older adults relative to young adults (Reed et al., 2014). The crucial distinction then, is that a positivity bias can be observed in older adults irrespective of memory patterns in young adults, whereas the positivity effect depends specifically on age-group differences in emotional memory. The young adult

reference group is therefore an essential component when studying relative age differences in the positivity effect. As suggested in Study 4, the emotional memory pattern in young adults from the community and from the university might not be identical. Whereas university students always showed a negativity preference (Studies 1 and 4) or a negativity bias (Studies 2 and 3), young adult non-students showed no such preference or bias toward negative material. Rather, they showed a positivity preference similar to that of older adults in Study 1 (Experiment 2 mixed condition) and Study 2 (negative video condition). A positivity effect might still have been present because older adults in Study 1 showed a positivity bias (positive > negative) that was not seen in non-student young adults of Study 4. However, these results suggest that the positivity effect would have at least been smaller had older adults been compared to non-student young adults. When considering the various terminology, it is important to keep in mind that although older adults might often show signs of a positivity *bias* in memory, this does not guarantee that there would also be a positivity *effect* across age groups when the appropriate young adult reference group is used.

### **The *How* and *Why* of the Positivity Bias in Aging**

The main purpose of my thesis was to inform us on how and why the positive memory bias seems to occur in aging. In my first paper, I examined extrinsic factors that influence emotion-enhanced memory in young adults, to see whether these would inform us of the cognitive processes required to produce a positivity bias in older adults. This work showed that when memory is tested after a brief delay, emotional memory in older adults could be fully explained by the level of semantic relatedness between items and the distinctive processing of positive stimuli relative to other types of stimuli. On the other hand, when these two cognitive factors were controlled and unavailable to older adults, then their positivity bias disappeared.

This shows how these two factors support the positivity bias in aging. These findings are consistent with previous work on the positivity bias and can help develop a useful cognitive framework to understand these findings (discussed in the next section).

The remaining thesis papers sought to explain why the positivity bias might occur specifically in older adults based on an intrinsic factor, mood. A review of the literature revealed consistent differences in mood between young and older adults at the start of experiments on emotional memory. In using mood manipulation protocols (with video or text), I was unable to show strong mood-congruent memory effects in either age group. Young adults' negativity bias was persistent despite the two mood manipulations (Studies 2 and 3). Older adults did not show any positivity bias, but their preference for positive stimuli over neutral stimuli was somewhat influenced by mood. In fact, they showed signs of mood-incongruent memory, because their positivity preference was present subsequent to watching a negative video. Overall, mood could not fully explain why there is a positivity bias in older adults specifically. Importantly, my final study showed that young adult university students and non-students show different patterns of emotional memory, with non-students resembling more closely older adults.

Taken together, these results show that the positivity effect in aging reflects a temporary contextual advantage for positive information that is not permanent or irreversible. Rather, the positivity effect depends in varying degrees on the context of study (relatedness and distinctiveness during encoding and/or retrieval), mood, and the young-adult reference group. It can be considered as the consistent 'absence' of a negativity bias in older adults.

### **Cognitive Mechanisms Behind the Positivity Effect**

In this thesis, I show that the positivity bias in older adults depends entirely on the semantic interrelatedness and distinctiveness of experimental items (Study 1). Past work on the positivity effect has focused on social (Carstensen et al., 1999; Charles & Carstensen, 2010) and neural factors (Leclerc & Kensinger, 2010, 2011; Mather et al., 2004; St. Jacques et al., 2009, 2010) that change with age, and some work has considered the impact of reduced cognitive capacity (Labouvie-Vief, 2003; Labouvie-Vief et al., 2010). But very little work has been done to develop a cognitive model of the positivity effect in aging that links to current models of emotion-enhanced memory (see Kensinger & Gutchess, 2017). This is useful and needed to describe the fundamental cognitive processes involved in the positivity effect.

The mediation theory serves as a useful starting point to explain the positivity effect in aging (Talmi, 2013; Talmi & McGarry, 2012; Talmi et al., 2013). Based on mediation theory, emotion-enhanced memory (EEM) can be entirely explained by three cognitive factors (when memory is tested within a short delay). This complements the modulation model (McGaugh, 2000, 2015), which accounts for the longer-lasting effects of emotion on memory (i.e., when memory is tested after many hours or days). According to mediation theory, semantic relatedness, relative distinctiveness, and attention can entirely explain immediate EEM in young adults. When stimuli are more interrelated, relatively distinct, or capture more attention, this can lead to the unequal distribution of resources in favour of emotional stimuli, resulting in their memory advantage (Ack Baraly et al., 2017; Talmi & McGarry, 2012). In Study 1, rather than measure or manipulate attention, I sought to minimize its impact by using a full-attention intentional-encoding task, as has been done elsewhere (Talmi & McGarry, 2012). In Study 1, emotional memory in older adults could be entirely explained by the remaining two factors:

semantic relatedness and distinctiveness. These results further support mediation theory by showing that these two cognitive factors also support emotional memory in older adults. Importantly, this shows that these processes are well preserved in aging. Overall, the mediation theory provides a useful framework for understanding the positivity effect in aging.

The results presented in Study 1 are consistent with many current findings in the literature. There was still a positivity bias shown in older adults when using mixed-emotion sets of stimuli, which is a common methodological procedure (e.g., Charles et al., 2003; Joubert, Davidson, & Chainay, 2018). Part of the reason why the positivity bias in older adults seems so robust in the literature could be due to the use of mixed-emotion tasks which encourage distinctive processing and stimulus sets that are potentially mismatched in their levels of semantic relatedness. Showing the abolishment of the positivity bias in older adults when controlling distinctiveness and semantic relatedness does not refute the existence of an aging positivity bias, it simply shows that the bias might be temporary and maximized by certain experimental designs. If, older adults have a permanent decrease in their memory for negative information, then this would be better investigated using unmixed sets of stimuli that reduce distinctive processing. For these reasons, it would be important to replicate the current findings by directly comparing the strength of the positivity effect when processing is distinctive or nondistinctive. There may be other factors influencing encoding and/or retrieval that are especially important in aging that should also be considered in a cognitive model of the positivity effect.

This work is also consistent with the view that the positivity effect is in some way a response bias that changes from young into older age (Kapucu, Rotello, Ready, & Seidl, 2008). Using a memory recognition task, Kapucu et al. (2008) showed that young and older adults had

similar recognition accuracy for positive and negative stimuli, yet each group had a different response bias for ‘old’ (‘remember’) responses. This would suggest that as adults age they *prefer* to remember positive information more so than negative information but their *ability* to retain the information is unchanged. The results of Study 1 support this interpretation in showing that older adults maintained the ability to recall all pictures equally well when distinctiveness and relatedness were equally matched across pictures. With the current set of methods we do not know whether participants in the mixed conditions were answering based on a response bias, but this would be useful to explore in future work.

Based on Study 1, I was able to show that two extrinsic factors, semantic relatedness and distinctiveness, were necessary for producing the positivity bias in older adults. But that does not inform us of why there is a relative advantage for positive stimuli when distinctive processing occurs. I therefore encouraged the distinctive processing in subsequent studies, while controlling item interrelatedness, to further examine whether the positivity bias could be explained by mood, an intrinsic variable often overlooked in aging research.

### **Mood Influences on Positive Memory**

There was no evidence of mood-congruent memory effects in either of the two experiments using mood manipulation. In this thesis, I tested whether being in a positive (or negative) mood would result in a positive (or negative) memory bias. Although the video mood manipulation was able to elicit positive and negative emotions in participants, this did not produce a positivity or negativity bias as was expected. The text priming task was less effective at altering participants’ moods and did not influence their memory in any way. Therefore, there was no support for a mood-congruent hypothesis of the positivity effect in aging.

Unexpectedly, there was some evidence of mood-incongruent memory in the video manipulation study (Study 2B). Overall, young adults showed a negativity bias in all conditions, whereas on average, older adults had no memory advantage in favour of positive or negative stimuli. Both young and older adults showed slight signs of mood-incongruent memory effects, however. The negativity bias in young adults was largest and statistically significant after they watched a positive video. Older adults showed a positivity preference (positive > neutral) after having watched a negative video but this was not significant after watching a positive or neutral video. Therefore, across all conditions the young adults showed a persistent negativity bias, which was strongest after a positive video. But the older adults' positivity preference only appeared after the negative video manipulation. These mood-incongruent memory effects resulted from a trending three-way interaction<sup>21</sup> ( $p = .087$ ) and would need to be replicated. Nonetheless, they are interesting because they directly refute our predictions.

These mood-incongruent memory effects could be understood within the Affect Infusion Model (AIM; Forgas, 1995, 2002). According to AIM, there are at least four different types of processing strategies available to a participant during a particular task that predict the strength of mood congruence. In this case, mood-incongruent memory could be explained by the second level, *motivated* processing. If participants were adopting a motivated processing strategy, they would be responding based on an external motivator rather than based on their current emotional state (Forgas, 1995). As suggested by Forgas and Ciarrochi (2002), mood incongruence can serve to regulate emotions. This could explain why older adults showed a positivity preference only when in the negative mood condition, if they were motivated to regulate their emotions and counter-act the negative mood induction. This is consistent with the view that the positivity

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<sup>21</sup> Age x Video Condition x Picture Type

effect serves as an emotion regulation strategy (Nashiro, Sakaki, & Mather, 2012) and to increase emotional satisfaction and well-being (Reed & Carstensen, 2012).

One benefit, but also potential limitation, is that AIM can account for both mood-congruent and mood-incongruent memory effects. In the context of the positivity effect in aging, it can be challenging to predict when older adults will adopt a substantive processing strategy requiring them to engage more elaborative encoding and retrieval (Eich et al., 2008), in which we might expect mood congruence, versus when they will adopt a motivated processing strategy favouring emotion regulation and satisfaction, in which we might expect mood incongruence. Part of the challenge is the general limited number of studies using experimental mood manipulation and testing the positivity effect. Mood-congruence has been shown in older adults in other aspects of cognition, such as in implicit learning (using a lexical decision task) and autobiographical memory recall, and in samples with depression or anxiety (for review, see Knight, Rastegar, & Kim, 2016). To my knowledge, there is no study that has used a positive and negative mood induction procedure in healthy older adults and young adults, to test early long-term memory as was done in the present thesis. Similar work done in attention has also shown mood-incongruence effects in older adults induced into a negative mood (Isaacowitz et al., 2008). Because there is a limited number of studies in this area, especially those testing early long-term memory and controlling for item interrelatedness, there is need to replicate the present findings to determine whether a positivity bias would more often result from a mood congruent or incongruent state.

### **Relevance of Appraisal Theory of Emotion**

Although I do not directly assess the appraisal theory of emotion in my work, the results would be consistent with this view. According to appraisal theory, a wide range of stimuli may

receive priority because of their personal relevance in a particular instance, rather than their inherent or absolute significance (Arnold, 1960; Roseman, 2011; Sander, Grandjean, & Scherer, 2005). Each event is appraised for its emotional relevance as it occurs based on several criteria (e.g., novelty, goal-relevance, normative significance, predictability, intrinsic pleasantness, and coping potential; Coppin & Sander, 2013). In Study 1, older adults' positivity bias resulted from an advantage given to positive stimuli when these stimuli were processed in competition with other stimuli. Certainly, when different emotional stimuli are in competition, positive stimuli may be considered of greater value because they are more relevant to older adults' social goals (Socioemotional Selectivity Theory; Carstensen et al., 1999), but this would not preclude other, more negative, stimuli from becoming relevant in other circumstances. In many cases, negative information may be more valuable than positive information (Baumeister et al., 2001). Once again, this is consistent with the view that the positivity effect is temporary and depends on the particular context at encoding and retrieval. Therefore, other information that is processed at the same time may influence what is appraised as most relevant to the person. Moreover, appraisal theory could also account for memory that is mood congruent or incongruent, depending on the goals of the individual (i.e., to maintain a current mood or to regulate emotions by changing moods).

Appraisal theory can also account for the enhanced memory observed for related-neutral compared to unrelated-neutral pictures as the former would rank higher on the evaluation criteria. For instance, a participant will be able to organize semantically-related neutral pictures more easily than unrelated-neutral pictures and may be able to attribute a greater personal or social significance to these related-neutral items that they would not have been able to do with seemingly random neutral pictures. But there are many possible confounding factors between

emotional and neutral stimuli that can be hard to control. The most common practice, in line with the dimensional view of emotion (Russell, 2003), is to preselect stimuli for an experiment based on ratings of valence and arousal obtained *prior* to the experimental manipulation. Appraisal theory provides an interesting alternative to studying memory and a way to possibly reduce confounds between stimuli by manipulating the goals of participants (e.g., Montagrin, Brosch, & Sander, 2013; Talmi et al., 2013). This would alter their appraisal of stimuli due to their different goals *during* an experiment rather than alter the stimuli themselves (e.g., memory for food in sated or hungry participants; Talmi et al., 2013). Appraisal theory provides an interesting alternative to studying emotion in the laboratory and is so far consistent with the current findings on the positivity effect reported here.

### **Implications for the Field**

#### **Socioemotional Selectivity Theory**

Socioemotional Selectivity Theory (SST) remains the most common explanation for the positivity effect in aging (Carstensen & DeLiema, 2018). According to SST, the positivity bias appears when people's perception of the future becomes more limited, leading them to focus on present-oriented goals rather than future-oriented goals (Carstensen & DeLiema, 2018; Carstensen et al., 1999; Reed & Carstensen, 2012). This is more commonly seen in older adults because they typically have fewer years left to live than young adults. Some reports have shown that adopting a limited view of the future leads people to prioritize emotional needs over knowledge acquisition (Carstensen & Fredrickson, 1998; Fung & Carstensen, 2006; Fung, Carstensen, & Lutz, 1999), yet very few have directly linked this to changes in memory (Barber et al., 2016).

In the current thesis, I took two approaches to consider the hypotheses of SST in my work. First, I included the future time perspective scale from Carstensen and Lang (1996) in Study 2 (video mood manipulation). Then, in Study 3, I directly crossed mood (positive or negative) and time perspective (future-oriented or present-oriented) in a written priming task. The purpose of these manipulations was to determine whether the positivity bias could be attributed to a more present-oriented perspective of time. In neither study was this the case. There was no effect of the manipulation on memory nor was self-reported time perspective correlated with memory. Indeed, previous work would suggest that future time perspective might even be indicative of a maladaptive emotional profile in older adults (Grühn et al., 2016). More work is needed to validate a method that can reliably manipulate both time perspective and mood to assess their independent contributions to the positivity effect. In studies that do not use experimental manipulation, it would be important to include a scale measuring time perspective in order to dissociate the effects of time perspective from those of chronological age (Grühn et al., 2016), because the two might be closely related. The future time perspective scale (Carstensen & Lang, 1996) has been used in studies on social goals and emotional satisfaction (e.g., Fung, Siu, Choy, & McBride-Chang, 2005), but has seldom been included in studies on memory. Despite the lack of conclusive evidence in support of SST in my thesis, these studies are in the right direction in that they seek to provide more substantive experimental evidence to support the hypothesis that shifting time perspective leads to shifts in emotional memory bias across the lifespan.

### **Methodological Considerations**

The work presented here underlines some key considerations when designing studies on the positivity effect in aging memory. Thorough consideration of methodological design is

crucial because these extrinsic factors—which are within the experimenter’s control—could be exaggerating the size and/or robustness of the positivity bias in older adults.

Careful selection of emotional and neutral stimuli matched on levels of semantic relatedness is important. When neutral stimuli are selected randomly from a database, they are likely to have fewer semantic links between them than emotional stimuli which are often easier to link thematically (Talmi & Moscovitch, 2004). There could also be differences in the interrelatedness of negative and positive stimuli. Negative information is more widely represented in memory (Baumeister et al., 2001) and might therefore be less tightly clustered and interrelated than positive information (Koch et al., 2016; Unkelbach et al., 2008). Because increased stimulus interrelatedness is likely to increase memory (Einstein & Hunt, 1980; R. R. Hunt & McDaniel, 1993), it is important to match all stimuli in semantic relatedness. This will help ensure that differences in memory are not attributed to confounds in stimulus interrelatedness. Future research could also compare the use of positive stimulus sets lower and higher in interrelatedness to examine their direct influence on the positivity effect in aging.

Researchers should also keep in mind the implications of using mixed (i.e., emotion-heterogeneous) sets of stimuli at encoding and retrieval. When using mixed designs, the distinctive processing of positive over negative material is maximized. This is useful and perhaps necessary when wanting to examine relative differences between positive and negative information when these are processed together. However, this would not inform us of a person’s potential to remember negative information, which could be greatly reduced in a mixed-emotion design. Researchers should use unmixed (i.e., emotion-homogeneous) sets of stimuli if they are studying older adults’ ability to remember positive and negative information, independent of one

another. More studies are needed directly comparing the effect of using mixed and unmixed designs on the presence and magnitude of the positivity bias.

Semantic relatedness and distinctive processing are especially important when the delay between study and test is relatively brief (e.g., a few hours or less), which is often the case in many previous studies of the positivity effect (e.g., Charles, Mather, & Carstensen, 2003). When a brief study-test delay is used, researchers should focus on factors that might influence encoding and/or retrieval, rather than consolidation per se. This is because any influence on ‘late’ long-term potentiation (i.e., ‘slow’ consolidation) could take several hours or days to complete (Kandel et al., 2014). When longer study-test delays are used, there is a need to consider and differentiate factors that influence early or late long-term potentiation. Framing these emotional memory effects within the appropriate theory (e.g., modulation model, McGaugh, 2015; mediation theory, Talmi, 2013) will shape how we understand and integrate these findings within the wider literature on emotion and memory.

Participant selection is also important. Not only is the over recruitment of university students potentially limiting the generalizability of findings, it could also be artificially enhancing the strength of the positivity effect in aging. Recruiting young adult non-students is certainly challenging. It demands more time, effort, and money—but it is worth the investment. Especially as it becomes ever more important to accurately characterize memory in healthy aging, it is crucial for our findings to generalize outside the laboratory. Researchers could take initiative to develop and implement better recruitment practices within their department, working with others to establish recruitment pools of non-student participants (such as the one at the

University of Ottawa<sup>22</sup>). Over time, the number of potential participants would grow, and this would serve useful to any field in which student performance might not easily generalize beyond the university.

### **Future Directions**

One final consideration not yet addressed is that of test delay. In Study 1, two different test delays were used: 1 minute and 45 minutes. There was a significant interaction between the delay of the test and the type of pictures correctly recalled. Participants recalled positive pictures more often than negative pictures, but only after the 45-minute delay. Although this did not significantly interact with age group, these results may have been driven by the older adult data because they were the ones to show a positivity bias. If this were the case, then the positivity bias might indeed become stronger over time, an effect also observed for emotion-enhanced memory in young adults (Yonelinas & Ritchey, 2015). Indeed, Knight et al. (2002) found stronger mood-congruent memory effects on a delayed recall test than on an immediate recall test when using a sad mood induction protocol. I did not further explore the effects of test delay in my subsequent thesis studies. I used only a brief (1 min) delay so that there would be less time in between the mood manipulations and recall, in order to maximize the chances of participants maintaining the desired mood. Because incidental task instructions were used, a longer recall delay could have also resulted in floor effects in memory. For these reasons I did not further consider test delay in my thesis work, but it is an interesting avenue to explore in future research.

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<sup>22</sup> <https://socialsciences.uottawa.ca/psychology/research/participate-research/ispr-community-pool>

## Conclusion

In conclusion, emotional memory seems to change with age—and positively so. There are consistent differences across age groups, and when an emotional memory bias is found, it is in favour of negative information in young adults and positive information in older adults. In general, the positivity effect in aging can be accurately described as the consistent ‘absence’ of a negativity bias in older adults. In this thesis, I show that semantic relatedness and distinctive processing are the underlying cognitive mechanisms supporting the positivity bias in older adults. Researchers generally do not consider these cognitive factors in their experimental designs which could be exaggerating the strength of the effect in previous work. A positivity bias could depend in varying degrees on the context of study (relatedness and distinctiveness during encoding and retrieval), the young-adult reference group, and possibly mood as well. In light of these results, I conclude that the positive memory bias in older adults likely reflects a temporary contextual advantage for positive information and that memory for negative information is well preserved under the right experimental conditions. Many older adults might even show a negative memory bias and this should not be viewed as signs of unhealthy aging. I have highlighted a number of key methodological factors that can influence the presence and magnitude of the positivity bias and these should be considered in future work.

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## Appendices

### Appendix A: Description of Video Clips in Study 2A

<b>Title</b>	<b>Length (min)</b>	<b>Target mood</b>	<b>Description</b>	<b>URL</b>
<i>Babies and dogs</i>	4:06	Positive	Compilation video of dogs or puppies playing with babies and consists of happy background music.	<a href="https://www.youtube.com/watch?v=p336IIjZC18">https://www.youtube.com/watch?v=p336IIjZC18</a>
<i>Babies laughing 1†</i>	2:57	Positive	Compilation video of babies laughing.	<a href="https://www.youtube.com/watch?v=L49VXZwfup8">https://www.youtube.com/watch?v=L49VXZwfup8</a>
<i>Babies laughing 2</i>	3:55	Positive	Compilation video of babies laughing.	<a href="https://www.youtube.com/watch?v=L49VXZwfup8">https://www.youtube.com/watch?v=L49VXZwfup8</a> ; <a href="https://www.youtube.com/watch?v=RK4x3Snzfo0">https://www.youtube.com/watch?v=RK4x3Snzfo0</a> ; <a href="https://www.youtube.com/watch?v=dmVzCf_G1-k">https://www.youtube.com/watch?v=dmVzCf_G1-k</a>
<i>Dogs and stairs 2†</i>	3:02	Positive	Compilation video of dogs trying to walk on stairs and consists of happy background music.	<a href="https://www.youtube.com/watch?v=gghfoRKVPCo">https://www.youtube.com/watch?v=gghfoRKVPCo</a>
<i>Baby dancing</i>	1:38	Positive	Baby watches and dances to the song “Single ladies” by Beyonce.	<a href="https://www.youtube.com/watch?v=DnjHMtUjIvQ">https://www.youtube.com/watch?v=DnjHMtUjIvQ</a>
<i>Baby saying “no no no”</i>	0:30	Positive	Baby in a bathtub. Parents asks the baby a question and the baby responds with “no”.	<a href="https://www.youtube.com/watch?v=OSPGOz2K0-U">https://www.youtube.com/watch?v=OSPGOz2K0-U</a>
<i>Baby with hiccups</i>	1:00	Positive	Two babies sitting side by side. One baby hiccups and the other baby laughs.	<a href="https://www.youtube.com/watch?v=z5-mOiQUcrg">https://www.youtube.com/watch?v=z5-mOiQUcrg</a>
<i>Child scared of monsters</i>	0:42	Positive	A child tells her mother what she will do if she sees a monster.	<a href="https://www.youtube.com/watch?v=OSPGOz2K0-U">https://www.youtube.com/watch?v=OSPGOz2K0-U</a>
<i>Dogs and stairs 1†</i>	4:03	Positive	Compilation video of dogs trying to walk on stairs and consists of happy background music.	<a href="https://www.youtube.com/watch?v=gghfoRKVPCo">https://www.youtube.com/watch?v=gghfoRKVPCo</a>

<i>Partly Cloudy</i>	5:00	Positive	A cloud creates different animals for a stork to deliver. In the end, the cloud and the stork become friends.	<a href="https://www.youtube.com/watch?v=7DmLkugdh9s">https://www.youtube.com/watch?v=7DmLkugdh9s</a>
<i>Presto</i>	4:31	Positive	Magician performs on a stage and tries to get a rabbit to cooperate who ends up playing tricks on the magician.	<a href="https://www.youtube.com/watch?v=D4Dnm6dkOVI">https://www.youtube.com/watch?v=D4Dnm6dkOVI</a>
<i>Children with cancer</i>	3:17	Negative	Various stories of children with cancer. Video is in black and white.	<a href="https://www.youtube.com/watch?v=C2B3H7B6n_U">https://www.youtube.com/watch?v=C2B3H7B6n_U</a>
<i>Child with leukemia</i>	4:31	Negative	Mother discusses her child's journey with leukemia.	<a href="https://www.youtube.com/watch?v=gWVOWVgXIm4">https://www.youtube.com/watch?v=gWVOWVgXIm4</a>
<i>Dog with lesions</i>	4:37	Negative	A veterinarian provides medical treatment for a dog.	<a href="https://www.youtube.com/watch?v=tcJwFCbqsQM">https://www.youtube.com/watch?v=tcJwFCbqsQM</a>
<i>Dog eye surgery†</i>	4:19	Negative	A veterinarian provides medical treatment for a dog.	<a href="https://www.youtube.com/watch?v=4nkx5CUfoNw">https://www.youtube.com/watch?v=4nkx5CUfoNw</a>
<i>Huntington's disease 1</i>	4:54	Negative	A son discusses the life of his mother who has Huntington's disease and its impact on his life.	<a href="https://www.youtube.com/watch?v=Zp6Am82fZ0o">https://www.youtube.com/watch?v=Zp6Am82fZ0o</a>
<i>Huntington's disease 2†</i>	5:08	Negative	Video shows the life of a mother with Huntington's disease. The video consists of background music and certain parts are narrated by her son.	<a href="https://www.youtube.com/watch?v=gyQP93EfKH8">https://www.youtube.com/watch?v=gyQP93EfKH8</a>
<i>StoryCorps 1</i>	4:58	Negative	An animated video where a couple share their love story.	<a href="https://www.youtube.com/watch?v=WNfvJr9164">https://www.youtube.com/watch?v=WNfvJr9164</a>
<i>StoryCorps 2</i>	1:57	Negative	An animated video where a male narrates his love story of his fiancé who passed away during the attack on 9/11.	<a href="https://www.youtube.com/watch?v=QgGQAr5hmRI">https://www.youtube.com/watch?v=QgGQAr5hmRI</a>
<i>Beaver</i>	5:43	Neutral	Sir David Attenborough narrates a beaver documentary.	<a href="https://www.youtube.com/watch?v=iyNA62FrKCE">https://www.youtube.com/watch?v=iyNA62FrKCE</a>
<i>Dali museum tour</i>	5:03	Neutral	A man discusses art works of Salvador Dali.	<a href="https://www.youtube.com/watch?v=WSLBtmOAvd4">https://www.youtube.com/watch?v=WSLBtmOAvd4</a>

<i>Dog competition</i>	4:12	Neutral	Judges evaluate owner and dog as they perform various tasks.	<a href="https://www.youtube.com/watch?v=_hzs2Ebf-W4">https://www.youtube.com/watch?v=_hzs2Ebf-W4</a>
<i>Ducks</i>	4:54	Neutral	Documentary of ducks.	<a href="https://vimeo.com/86610300">https://vimeo.com/86610300</a>
<i>Fish</i>	1:23	Neutral	Sir David Attenborough narrates a documentary about different fish living in the Red Sea.	<a href="https://www.youtube.com/watch?v=z7667jwwX00">https://www.youtube.com/watch?v=z7667jwwX00</a>
<i>Hannah and her sisters</i>	1:30	Neutral	Two women shopping in a store.	<a href="https://www.youtube.com/watch?v=fHxeOvCwh6E">https://www.youtube.com/watch?v=fHxeOvCwh6E</a>
<i>Interview</i>	4:14	Neutral	Two men sitting across from one another discuss the brain and evolution.	<a href="https://www.youtube.com/watch?v=fGKdh-3btkQ">https://www.youtube.com/watch?v=fGKdh-3btkQ</a>
<i>Library tour†</i>	4:53	Neutral	A man gives a tour of his office.	<a href="https://www.youtube.com/watch?v=Buvksf9-q5U">https://www.youtube.com/watch?v=Buvksf9-q5U</a>
<i>Turtle</i>	3:54	Neutral	Sir David Attenborough narrates a documentary of sea creatures.	<a href="https://www.youtube.com/watch?v=z7667jwwX00">https://www.youtube.com/watch?v=z7667jwwX00</a>
<i>Van Gogh tour†</i>	5:17	Neutral	Two men discuss paintings of Vincent van Gogh.	<a href="https://www.youtube.com/watch?v=gc-2ArYE9NY">https://www.youtube.com/watch?v=gc-2ArYE9NY</a>

*Note.* †These videos were selected for the mood manipulation task in Study 2B.

## Appendix B: Priming Texts in Study 3

<p><b>Future-Positive Orientation – 163 words</b> Readability: Level 8</p> <p>People keep living longer and longer. There are more centenarians today than there were 20 years ago, and it is even possible that you might <i>live to be 120</i>. Because people are living longer – their quality of life and well-being will improve.</p> <p>Future advancements in science will make it possible for seniors to develop stronger immune systems so they can live a long, happy life. That means that you have a high chance of living to 120 years while remaining in constant good health. In addition, research shows that as we age our social and emotional connections with others significantly improve. We develop more meaningful and stronger bonds with those around us, leading to an overall increase in psychological well-being. Living until 120 years will simply give us more time to embrace life.</p> <p>As you answer the following questions, please plan for a future in which you live to be 120. Assume you are in good health with a high quality of life.</p>	<p><b>Future-Negative Orientation – 159 words</b> Readability: Level 9</p> <p>People keep living longer and longer. There are more centenarians today than there were 20 years ago, and it is even possible that you might <i>live to be 120</i>. Although people are living longer – their quality of life and well-being may decline.</p> <p>As we age, we are more at risk for developing illnesses such as dementia or heart disease. You may live to 120 years old but with reduced physical abilities and poorer health. In addition, research shows that our social and emotional connections with others significantly decline over time. A large proportion of older adults report feelings of loneliness and isolation, leading to an overall decline in psychological well-being. Living until 120 years will simply stretch out any physical or emotional problems that a person may have.</p> <p>As you answer the following questions, please plan for a future in which you live to be 120. Keep in mind that your health and quality of life could greatly decrease.</p>
<p><b>Present-Positive Orientation – 165 words</b> Readability: Level 8</p> <p>People can never know when life will end. Yet much research shows that we spend too little time focusing on <i>the present moment</i>.</p> <p>Live each day as if it were the last. Try to do activities that you enjoy every day. Take a moment now to consider what makes you happy in life, whether it be talking with a friend, reading a novel, or perhaps even walking outdoors. If you could dedicate thirty minutes of each day to doing what you love, your overall quality of life and psychological</p>	<p><b>Present-Negative Orientation – 151 words</b> Readability: Level 8</p> <p>People can never know when life will end. Yet much research shows that we spend too little time focusing on <i>the present moment</i>.</p> <p>While some are fortunate to live long lives, many die young. More and more young adults die in car accidents each year, due to impaired driving and texting. Some young adults may even develop life-threatening illnesses or incurable diseases. This can lead to decreased physical and mental health. You may be in constant pain or even live in a hospital bed.</p>

<p>well-being would significantly improve. Research shows that focusing on each day, one at a time, improves physical and mental health. This will ensure that no matter how long we have to live, we will always be happy, embracing life to its fullest.</p> <p>As you answer the following questions, please plan for a future in which you only have 6 months left to live. Imagine you could spend that time doing what you love most in life.</p>	<p>Although you may occasionally visit with friends and family, most of your day would be spent alone. This would produce feelings of loneliness and isolation, leading to an overall decline in psychological well-being.</p> <p>As you answer the following questions, please plan for a future in which you only have 6 months left to live. Keep in mind that your health and quality of life could suddenly deteriorate.</p>
<p style="text-align: center;"><b>Neutral Condition – 166 words</b> Readability: Level 9</p> <p>One of the most widely-grown vegetables in Canada is the potato. It has five stages of development during its short life cycle. This can take anywhere between three to four months. Because the potato grows underground, not all of the changes that take place are visible. During the first stage of growth, the eyes from the potato piece sprout above ground to form the stem and leaves. Then photosynthesis begins and the plant continues to grow. Warmer temperatures and lots of sunlight are needed during these early phases to help the plant grow. In the next phase, the underground stems will start growing just below the soil surface. The plant now depends on lots of water to continue growing underground. The underground stems will grow significantly during the fourth stage where they build up water, carbohydrates, and other nutrients. In the final maturation phase, the above ground portion of the plant will slowly die as photosynthesis slows down. The potatoes will then be ready to harvest.</p>	
<p style="text-align: center;"><b>Control Condition</b> In the control condition, there will be no priming text before the memory task.</p>	

## Appendix C: Word Categories in Study 3

The following LIWC2015 (Pennebaker et al., 2015) categories were included in the MANOVA.

<b>Summary Dimensions</b>	• Future focus	<b>Personal Concerns</b>
• Word count	<b>Affect</b>	• Work
• Tone	• Positive emotions	• Leisure
<b>Biological Processes</b>	• Negative emotions	• Home
• Body	• Anxiety	• Money
• Health*	• Anger	• Religion
• Sexual	• Sad	• Death
• Ingest	<b>Relativity</b>	<b>Cognitive Processes</b>
<b>Drives</b>	• Motion	• Insight
• Affiliation	• Space	• Causal
• Achievement	• Time	• Discrepancies
• Power	<b>Social</b>	• Tentative
• Reward	• Family	• Certainty
• Risk	• Friends	• Differentiation
<b>Time Orientation</b>	• Female	
• Past focus	• Male	
• Present focus		

\*Difference in written output between *present* and *future* conditions was significant after applying a Holm-Bonferroni correction.