Autobiographical Memory Retrieval to Musical Cues in Healthy Older Adults

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ABSTRACT

JACLYN HENNESSEY FORD: Autobiographical Memory Retrieval to Musical Cues in Healthy Older Adults
(Under the direction of Kelly S. Giovanello)

Research suggests that age-related changes are apparent in autobiographical memories when the qualitative content of the memories is examined. For example, older adults retrieve overly general memories (i.e. not restricted to a single event) relative to young adults' specific memories (the *overgenerality effect*) and rate their memories as more positive than young adults (the *positivity effect*). The majority of studies reporting these effects instruct participants to retrieve specific memories, thereby requiring participants to maintain task goals and inhibit inappropriate responses. Because these processes are impaired in healthy aging, these requirements may contribute to age-related differences in memory retrieval. To isolate underlying differences in memory representations, the current project utilized an autobiographical memory paradigm in which instructions were manipulated to separate age-related differences in underlying representations from the ability to follow task instructions. Music was selected as a retrieval cue due to its unique capability to elicit specific emotional memories without explicit retrieval instructions. Experiment 1 compared young and older adults' autobiographical memories under restricted and unrestricted retrieval conditions. The age-related overgenerality effect was reduced when participants were provided with unrestricted instructions, suggesting that this effect partially reflects a difficulty maintaining task instructions. The positivity effect was not observed in any condition, suggesting that memories cued by music may not exhibit the effect. Experiment 2 utilized event-related functional neuroimaging to examine age-related changes to the neural networks recruited during emotional and specific autobiographical memory retrieval. Young and older adults engaged many of the same regions during retrieval of specific events, including inferior and superior parietal lobes, medial temporal lobe, and prefrontal cortex, suggesting that retrieval in both groups may rely on similar underlying cognitive processes. During emotional memory retrieval, older adults recruited the medial prefrontal cortex to a greater extent than young adults. Importantly, although a positivity effect was not observed in the behavioral data, such age-related neural differences suggest that young and older adults process emotional memories differently. The current study provides valuable insight into how memory representations change with time and experience, highlighting circumstances that exaggerate and diminish age-related changes, and neural differences that exist when behavior is equivalent.

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CHAPTER 1: INTRODUCTION

Autobiographical memory is intimately involved in one's everyday experience. Despite this important role, it remains a memory system in which age-related changes are not fully understood. One review recently labeled autobiographical memory as being relatively impervious to the effects of aging (Hedden & Gabrieli, 2004). This designation arises from studies in which young and older adults are able to recall equal numbers of autobiographical memories from all periods of life (Howes & Katz, 1992). Although these results demonstrate that retrieval *success* may be relatively equivalent between groups, the nature of autobiographical memory research makes it difficult to compare retrieval *accuracy* in most cases. As such, more complex study designs have been required to identify differences in young and older adults' autobiographical memory retrieval.

Understanding age-related changes to autobiographical memory retrieval is particularly important due to the role of personal memories in daily functioning. Changes in autobiographical memory are exceptionally disturbing to older adults, who often cite these changes among their primary cognitive complaints (Markowitsch, Welzer, & Emmans, 2010). As such, it is essential for researchers to understand why personal memories change as we age and, more importantly, to delineate factors that can exaggerate or minimize the effects.

Recent research has demonstrated that age-related changes are apparent in autobiographical memory retrieval when the qualitative content of the memories is examined.

First, older adults tend to retrieve autobiographical information that is overly general (i.e. not restricted to a single event) relative to young adults' specific memories (see Piolino, Desgranges, & Eustache, 2009). This *overgenerality effect* in older adults' retrieval has been demonstrated using a variety of measurements and retrieval cues (e.g. Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino et al., 2010; Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009). Second, older adults retrieve memories that are rated as more positive overall, relative to those of young adults (Dijkstra & Kaup, 2005; Singer, Rexhaj, & Baddeley, 2007). This *positivity effect* has been extensively reviewed in the episodic memory literature (Mather & Carstensen, 2005), but has been less studied in autobiographical memory. The current project examined the overgenerality effect and positivity effect in the context of additional factors that may influence them, such as executive control function and level of depressive symptomatology.

Overgenerality Effect in Older Adults' Autobiographical Memories

Specific autobiographical memories (i.e. memories for events lasting no longer than a single day) involve a complex interplay of specific event details and abstract knowledge about the self (Conway & Pleydell-Pearce, 2000; Levine et al., 2004). The conceptual foundation of an autobiographical memory is formed by abstract personal knowledge (i.e., who you were, where you lived, and what you were doing at a particular time in your life), but the substantive content is made up of event-specific sensory, emotional, and contextual details (i.e., specific details regarding how you felt and what you perceived during a particular event; Conway & Pleydell-Pearce, 2000). Conway and colleagues (Conway & Pleydell-Pearce, 2000) have described memories containing these particular details, or *event specific memories*, as the ultimate level in a hierarchical memory system. These memories include the vivid imagery, mental time travel, and autonoetic consciousness (i.e. the ability to mentally re-experience the event; Tulving, 1985) typically associated with laboratory episodic memories (Piolino, Desgranges, & Eustache, 2009).

Although many autobiographical memories are retrieved as specific events, it is also possible to retrieve more general autobiographical information (Piolino, Desgranges, & Eustache, 2009). This information can be in the form of abstract knowledge about the self (i.e. *lifetime period knowledge*; Conway & Pleydell-Pearce, 2000), or an extended memory for a set of repeated events or a period of time longer than one day (i.e. *general event memory*; Conway & Pleydell-Pearce, 2000). These general autobiographical memories are abstracted from multiple specific events and recalled as semanticized personal knowledge.

Laboratory studies have consistently demonstrated that episodic memory is disproportionately affected by healthy aging, causing older adults to compensate by relying on their relatively intact semantic memory (Mitchell, 1989). Recent studies have established that a similar pattern exists in autobiographical memory retrieval, with older adults retrieving overly general autobiographical memories in place of specific memories (Addis, Wong, & Schacter, 2008; Baron & Bluck, 2009; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino et al., 2010; Piolino, Desgranges, Benali, & Eustache, 2002; Piolino et al., 2006; Piolino, Desgranges, & Eustache, 2009; Ros, Latorre, & Serrano, 2010). In these studies, older adults often report abstract knowledge or generalized memories when task instructions explicitly require retrieval of a specific autobiographical memory.

An overgenerality effect in older adults' autobiographical memories has been examined using a variety of methods. The Autobiographical Memory Test (AMT), originally implemented by Williams and Broadbent (1986), has typically been used to study specificity in individuals with emotional disorders (see Williams et al., 2007 for review), but was recently utilized in a comparison of healthy young and older adults (Ros, Latorre, & Serrano, 2010). In the AMT, participants are presented with positive and negative word cues and are instructed to retrieve a *specific* autobiographical memory in the allotted time frame (thirty seconds to two minutes). Researchers use pre-established guidelines to rate each memory as specific or general. In their examination of healthy aging, Ros and colleagues (2010) gave young and older adults one minute to retrieve a specific autobiographical memory for each cue. Despite the fact that all participants received the same instructions to retrieve a specific memory, older adults recalled a greater number of categorical memories and a smaller number of specific memories compared to young adults.

Other tests of memory specificity have included structured interviews to directly evaluate semantic and episodic autobiographical memory (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino, Desgranges, Benali, & Eustache, 2002; Piolino et al., 2010). Piolino and colleagues (2002) used two questionnaires to interview participants separately about abstract personal knowledge and specific events. The results from these questionnaires demonstrated significantly greater age-related impairment when participants were asked questions regarding autobiographical episodes, relative to questions regarding autobiographical knowledge. Additionally, this disproportionate deficit became greater with the increasing age of the participants (from 50 to 79 years).

The Autobiographical Interview (AI) was also developed to measure the differential contributions of semantic and episodic details within a single mnemonic narrative (Levine et al., 2002). In the AI, transcribed memories are segmented into units of information that are coded as either “external” (i.e. semantic/irrelevant) or “internal” (i.e. episodic and central to the memory). Levine and colleagues (2002) demonstrated that older adults' narratives contained more external details and fewer internal details than those provided by young adults. This pattern held even when participants were provided with additional retrieval support in the form of probing questions. Addis and colleagues (2008) replicated this finding with autobiographical memories, as well as with narratives of possible future events. The AI has also been used to compare the types of details that individuals include in their narratives. In two separate studies, older adults retrieved fewer episodic details reflecting actions, locations, and thoughts than did young adults (Baron & Bluck, 2009; Levine et al., 2002). In addition, older adults retrieved more details that were regarded as irrelevant or "external" to the central theme of the memory (Baron & Bluck, 2009; Levine et al., 2002).

To further investigate age-related changes in retrieval of personal information from varying levels of specificity, a recent study utilized a verbal fluency method that targeted autobiographical information (Piolino et al., 2010). The Verbal Autobiographical Fluency (VAF) test gives participants two minutes to retrieve as much information as possible from each of four levels of autobiographical specificity (i.e. lifetime period, general event, event specific, and event detail) in descending order. Piolino and colleagues showed that older adults performed significantly worse in the VAF test than younger adults, with age-related impairments increasing for more specific memory levels.

Another recently developed memory procedure investigates measures of memory specificity, as well as the subjective experience of remembering (Piolino et al., 2006). In the *Test Episodique de Mémoire du Passé autobiographique* (TEMPau), participants are cued by a theme or question (e.g. "a journey"), as well as a particular period in time (e.g. 5-10 years ago). Piolino and colleagues (2006) gave participants precise instructions to retrieve a specific autobiographical memory with as many details as possible and prompted individuals with general cues to assist in specific retrieval. Consistent with previous studies, young adults' memories were scored as being significantly more specific than those retrieved by older adults.

In summary, healthy older adults consistently retrieve overly general autobiographical memories when provided with instructions to retrieve a memory for a specific event. This has been demonstrated in studies that measure the specificity of narratives as a whole (Piolino et al., 2006; Ros et al., 2010), those that examine the episodic and semantic contributions to a single narrative (Addis et al., 2008; Levine et al., 2002), and those that separately evaluate retrieval of specific and general information in individual questionnaires (Piolino et al., 2010; Piolino et al., 2002). The reduction in specificity manifests itself as reduced retrieval of relevant episodic details, as well as the increased retrieval of irrelevant and semantic information (Addis et al., 2008; Levine et al., 2002).

The current study extends prior research by identifying circumstances in which the age-related overgenerality effect is exaggerated or diminished. Specifically, the current study examines the effects of task manipulations, as well as individual differences across subjects. In addition, here I utilize multiple measures of specificity to determine whether memory-level ratings (i.e., evaluations of the entire narrative) produce the same pattern of results as detail-level ratings (i.e., proportion of details ratings as "internal").

Positivity Effect in Older Adults' Autobiographical Memories

In addition to the aforementioned overgenerality effect, older adults also exhibit a *positivity effect,* or a tendency to retrieve autobiographical memories that are self-rated as more positive than those retrieved by younger adults (Dijkstra & Kaup, 2005; Singer, Rexhaj,

& Baddeley, 2007). A large body of research has demonstrated that a positivity *bias* (i.e. the tendency to retrieve more positive than negative autobiographical memories; see Bower, 1981), exists for both young and older adults when retrieving autobiographical memories, but the *positivity effect* in healthy aging suggests that the bias is enhanced in older adults. This effect has been investigated extensively in the episodic memory literature (see Mather & Carstensen, 2005 for review) and a number of recent studies have attempted to discern whether this pattern extends to autobiographical memory retrieval, but the research is currently inconclusive.

In an early study, Field (1981) collected retrospective reports of childhood happiness from a group of adults over the course of 40 years. In their thirties, only 35% of participants reported being "generally happy" during childhood. However, by their seventies, 85% of the same adults provided a "generally happy" rating. Field concluded that adults' memories for their personal past become more positive as they age. This shift in memory toward a more positive representation has been described in terms of a fading negativity effect where negative information fades faster than positive information over time (Walker, Vogl, & Thompson, 1997).

The tendency for negative information to fade faster than positive information cannot be the only explanation for the age-related positivity effect. Several studies have looked at the shift in representation in groups of young and older adults to determine whether age influences the extent to which events are positively reappraised over short periods of time (Kennedy, Mather, & Carstensen, 2004; Levine & Bluck, 1997; Mather & Johnson, 2000; Ready, Weinberger, & Jones, 2007). The results of these studies indicate that older adults are more likely than young adults to overestimate how happy or healthy they reported being in the past (Kennedy et al., 2004; Ready et al., 2007), attribute positive characteristics to the previous choices (Mather & Johnson, 2000), and forget the intensity of negative affect associated with a past event (Levine & Bluck, 1997). In these studies, the shift in positivity is greater for older adults than for young adults, indicating that the shift towards positive information in old age is not solely due to fading negativity.

In addition to shifts in positive and negative judgments, the positivity bias can also be measured by calculating retrieval success when young and older adults are instructed to retrieve memories of positive and negative events. When asked for four positive, four neutral, and four negative autobiographical events, older adults successfully retrieved fewer negative events than younger adults, but the two groups retrieved the same number of neutral and positive events (Fernandes, Ross, Wiegand, & Schryer, 2008). One week later, all participants were tested for their memory of these events. The positivity bias was not observed for re-retrieval of accurate memories, as young and older adults successfully recalled equivalent proportions of the positive and negative memories previously reported. However, older adults falsely remembered more inconsistent positive information than young adults, supporting the suggestion that older adults, to a greater extent than young adults, may misremember past events in a more positive way over short periods of time.

Finally, a number of autobiographical memory studies investigating the positivity bias in aging focus on the subjective ratings of affect associated with personal memories retrieved by young and older adults. In these studies, older adults rated their autobiographical memories more positively (Dijkstra & Kaup, 2005; Singer et al., 2007) than young adults. Of particular interest, when young and older adults were explicitly instructed to retrieve autobiographical memories that were negative in valence, older adults still rated their memories as more positive than young adults (Comblain et al., 2005), once again demonstrating the tendency in older adults to reappraise memories to reduce negative content. Importantly, these studies required participants to select highly important memories from their past. It is possible that cued memories may not result in the same positivity effect in older adults (Schlagman et al., 2009).

Although the findings described above suggest that the positivity effect identified in laboratory studies of episodic memory may extend to autobiographical memory, data from other studies are inconsistent with this view. Two recent studies have focused on the emotional content of the actual autobiographical narratives provided by young and older adults (Alea, Bluck, & Semegon, 2004; Bluck & Alea, 2009). In these studies, participants were asked to record their memories, which were then transcribed and coded by researchers. Each emotional expression was coded as either positive or negative (Bluck & Alea, 2009) or according to the discrete emotion it represented (e.g. sadness, happiness, surprise, etc; Alea et al., 2004). The positivity effect, as measured by the proportion of positive emotional expressions in older adults relative to young adults, was not identified in either study. In fact, the data from these studies indicate that older adults had a larger proportion of references to sadness (Alea et al., 2004) and a smaller proportion of positive references (Bluck & Alea, 2009). These findings suggest that the positivity effect may not manifest itself in the actual mnemonic content, but is instead a product of older adults' altered appraisal of the emotion.

To date, research on the age-related positivity effect in autobiographical memory is inconclusive. However, sufficient data exist to suggest that adults evaluate their pasts in a more positive way as they age. This effect has been demonstrated by studies showing that older adults are more likely than young adults to re-evaluate past decisions and events in a more positive light over time (Kennedy, Mather, & Carstensen, 2004; Levine & Bluck, 1997; Mather & Johnson, 2000; Ready, Weinberger, & Jones, 2007). In addition, older adults' ratings of autobiographical events are more positive than those of young adults (Dijkstra & Kaup, 2005; Singer et al., 2007; but see Schlagman et al., 2009).

The inconsistencies apparent in the positivity effect make it an important topic for future research. The current study utilized positive and negative retrieval prompts to elicit autobiographical memories in young and older adults, and compared valence ratings given for these memories. In addition, the current study examined how task manipulations and individual differences across subjects minimize or maximize the effect.

Executive Control Processes in Older Adults' Autobiographical Memory Retrieval

Although the exact definition of what is considered an "executive control process" varies within the literature, most researchers include shifting/task switching, updating, and inhibition (Piolino et al., 2010). In intentional autobiographical memory retrieval, executive control processes are responsible for executing the search process, maintaining task instructions, monitoring memories based on task and personal retrieval goals, and inhibiting inappropriate memories. Executive control processes are particularly important during retrieval of *specific* event memories. Voluntary retrieval of a specific autobiographical memory requires participants to navigate through a hierarchy of autobiographical information from abstract personal knowledge to specific event details, a task that requires controlled search processes (Conway and Pleydell-Pearce, 2000). In addition, executive control is required to maintain and implement task instructions, including the inhibition of inappropriate overly general responses that are automatically triggered by the retrieval cue.

Recent research also suggests that individuals recruit top-down executive control processes to enhance positive and diminish negative information during memory retrieval (Mather & Carstensen, 2005; Mather & Knight, 2005). According to this research, the positivity effect requires a strategic shift in resources to successfully alter retrieval, making the effect dependent on executive control functioning (Mather & Knight, 2005). Of note, one study suggests that older adults, and not young adults, use executive control processes to regulate the emotional content of memories (Mather & Knight, 2005). These studies suggest that age-related changes in motivation cause older adults, but not young adults, to recruit available resources to regulate emotion (Mather, 2004). However, the positivity effect has also been identified in involuntary autobiographical memory retrieval (Schlagman et al., 2009). Involuntary autobiographical memories are explicit memories that are mediated by automatic processes (Berntsen, 1996; Berntsen, 2007; Mace, 2007; Mandler, 2007), suggesting that such automatic processes may also contribute to the positivity effect.

Autobiographical Memory Retrieval and Task Demands

Many studies that have examined the overgenerality and positivity effects have confounded their research questions by introducing additional executive control requirements into their autobiographical memory task instructions. In particular, most studies require that participants retrieve a *specific* autobiographical memory. In tasks that require retrieval of a specific memory, participants are required to maintain the "specificity" goal in mind and actively inhibit overly general information (Williams et al., 2007; Williams et al., 2006).

Previous studies have demonstrated that older adults have deficits in the inhibition of irrelevant information (Hasher, Stoltzfus, Zacks, & Rypma, 1991; West & Bell, 1997)**,** self-initiated strategic operations (Craik & Grady, 2002; Craik, Morris, & Gick, 1990), and the maintenance of information in working memory (Daigneault & Braun, 1993). Recently, Braver and colleagues suggested that older adults have a deficit in actively representing, updating, and maintaining task goals that may interfere with a number of cognitive processes, such as memory retrieval (Braver & Barch, 2002; Braver, Satpute, Rush, Racine, & Barch, 2005; Braver & West, 2008). As such, these added task requirements may put older adults at a disadvantage, making it difficult to measure differences in the actual autobiographical memory retrieval process.

Although no study has directly examined the effects of task demands on the overgenerality and positivity effects in the older adult population, related research suggests an important role of executive control requirements in both effects. In one recent episodic memory study, dividing attention during encoding of emotional images eliminated the positivity bias in older adult participants. In fact, older adults in the divided attention condition showed a negativity bias, remembering negative stimuli better than positive (Mather & Knight, 2005). Importantly, membership in the dual-task condition was not related to a reduction in the positivity bias in young adults as it had been in older adults. In this study, young adults always demonstrated a negativity effect, recognizing more negative than positive images at retrieval. This study represents a rare case in which reducing the executive control capability of older adults actually equates their performance with young adults. These results suggest that older adults, but not young adults, use executive control processes to successfully regulate emotional retrieval.

A divided-attention task was also used by Williams and colleagues (2006, Exp. 3) to examine the role of executive control in autobiographical memory retrieval specificity in healthy young adults. Their experiment demonstrated that young adults retrieve more general autobiographical memories in a dual-task condition relative to a full attention condition. The decrease in specific retrieval suggests that the executive control requirements of the dual-task interfered with the young adults' ability to retrieval a specific memory. It is possible that older adults, who have lower executive control abilities overall, may suffer from similar interference when autobiographical memory tasks include increased retrieval demands.

Finally, two recent studies directly examined the role of task instruction in two populations who typically exhibit the overgenerality effect (i.e., individuals with depression, Dalgleish et al., 2007; individuals with PTSD, Dalgleish et al., 2008). These studies used a reverse memory instruction (i.e., "Please retrieve a *general* autobiographical memory") to determine the extent to which difficulty maintaining and implementing the *specific* memory instruction contributed to the effect. The authors proposed that general memory instructions would result in a reversed effect (i.e., an overspecificity effect) if the original overgenerality effect was primarily driven by an inability to maintain and implement task instructions. Specifically, individuals who typically have trouble inhibiting *general* memories according to task instruction would now have difficulty inhibiting *specific* memories (e.g., individuals with depression; Dalgleish et al., 2007). However, if overgenerality in a given population was actually driven by other factors (e.g., emotion regulation), the overgenerality effect would persist in the population, regardless of instruction, as these other factors would still result in a tendency to retrieve general memories (e.g., individuals with PTSD; Dalgleish et al., 2008). These studies were important, as they demonstrated that task instructions can have an important influence of the overgenerality effect. In addition, these studies demonstrate that there are multiple potential factors underlying the effect.

The current study examined how task demands impose additional requirements on older adults, potentially altering the overgenerality and positivity effects. *Specific* and *general* retrieval instructions were compared to an unrestricted retrieval instruction where participants were not explicitly instructed to retrieve a certain type of memory. Although one recent study employed an unrestricted retrieval task to measure the overgenerality and positivity effects in older adults (Schlagman et al., 2009), this study did not compare conditions with different task demands. As such, it is unknown whether any systematic differences exist between autobiographical memories retrieved using different instructions. The aforementioned studies suggest that reductions in task demands may have differential effects on the positivity and overgenerality effects in older adults. Specifically, although the reductions in task demands may enhance the positivity effect (i.e. they may increase the difference in memory valence), the overgenerality effect may be diminished.

Autobiographical Memory Retrieval and Executive Control Ability

The relationship between autobiographical memory studies and executive control processes may also be important to consider when examining age-related changes. Recent research has revealed that increases in executive control ability correspond to decreases in overgeneral memory (Addis et al., 2008; Birch & Davidson, 2007; Ros et al., 2010). Moreover, Piolino and colleagues (2010) demonstrated that the relationship between age and autobiographical memory specificity in their study was largely mediated by scores on executive control tasks of updating and inhibition.

Currently, no study has examined the association between autobiographical memory positivity and measures of executive control. However, the episodic memory literature predicts a strong positive correlation between these two measures, where increased executive control ability would be associated with an increase in the positivity effect in older adults (Mather & Knight, 2005). Older adults with higher scores on tests of executive attention efficiency, memory span, and updating/refreshing demonstrated a larger positivity effect in their memory for emotional pictures (Mather & Knight, 2005). As was previously noted in their divided attention experiment, Mather & Knight (2005) demonstrated that reduced performance on executive control tasks was not related to changes in memory positivity in young adults. The current study served as an extension of these prior studies by examining the same relationships in an autobiographical memory task that utilized an unrestricted retrieval paradigm with reduced task demands.

The Interaction of the Overgenerality and Positivity Effects

A secondary question in the proposed research project concerns the interaction of the overgenerality and positivity effects in autobiographical memory retrieval. To date, no studies have examined how an increased tendency to retrieve positive autobiographical memories might influence the overall level of memory specificity. At the item level, memories for positive events are retrieved as more detailed and specific than those for negative events (D'Argembeau, Comblain, & Van der Linden, 2003; Ford et al., *under review-a*; Ros et al., 2010; Talarico, Berntsen, & Rubin, 2009). However, no study has examined specificity as a function of individual differences in positive memory retrieval.

Many researchers have investigated memory specificity in individuals with emotional disorders, such as depression (see Williams et al., 2007 for review). These studies demonstrate that individuals with emotional disorders retrieve fewer specific memories than healthy controls, suggesting that negative mood might be related to general memory retrieval.

This line of research suggests a relationship between memory valence and specificity, but does not examine it directly.

Two separate lines of research provide evidence as to the nature of this relationship. Previous research suggests that the overgenerality effect and positivity effect may both rely on executive control processes (Addis et al., 2008; Birch & Davidson, 2007; Mather & Knight, 2005; Ros et al., 2010). If both effects are strongly associated with executive control ability, then individuals with high scores on executive control tasks should have high levels of positive *and* specific memory retrieval, leading to a positive relationship between the two variables.

A separate line of research suggests that there may be a negative relationship between specificity and positivity in older adults' memory retrieval. The Socioemotional Selectivity Theory (SST) states that affect regulation becomes more important to adults as they age (Carstensen, 1995; Carstensen, Isaacowitz, & Charles, 1999), suggesting that older adults shift their personal goals from factual accuracy to emotional gratification (Carstensen, 1992). When an older adult focuses attention and resources on the emotional connection between an event and themselves, they shift focus away from the event, reducing the importance of specific event details (Hashtroudi, Johnson, & Chrosniak, 1990; Mather, 2004). According to this perspective, the recruitment of additional resources to regulate emotional aspects of a memory may contribute to the lack of resources available to access specific details. As such, older adults who have an increased level of positive memory retrieval may have a *decreased* level of specific memory retrieval, producing a negative relationship between the two variables. This suggestion has been supported by studies in which an emotional shift in focus reduced memory details in young adults' memories (Hashtroudi et al., 1994).

In the current study, I examined the relationship between an individual's tendency to retrieve positive memories and the specificity of their memories in an attempt to dissociate these two theoretical accounts. This relationship was examined separately for young and older adults. In addition, the memory-level specificity-valence relationship (i.e., positive memories being more specific) was investigated in both groups.

Neural Correlates of Autobiographical Memory Retrieval

In addition to investigating the cognitive mechanisms underlying the positivity and overgenerality effect, the current project also examined the neural correlates of these effects. Autobiographical memory retrieval engages an extensive core memory network (including frontal, temporal, and posterior regions) that has been identified in neuroimaging studies with young adults (Maguire, Henson, Mummery, & Frith, 2001; Svoboda, McKinnon, & Levine, 2006), as well as healthy older adults (Maguire & Frith, 2003; Piefke & Fink, 2005). In a recent review, Cabeza & St. Jacques (2007) highlighted the core regions of this network, including lateral and medial regions of the prefrontal cortex (PFC), the medial temporal lobe (MTL), and visual cortex.

Neuropsychological studies have compared patients with distinct patterns of neural damage. Medial temporal lobe damage is associated with global autobiographical memory damage, with some graded memory loss for personal knowledge (Kirwan, Wixted, & Squire, 2008; Piolino et al., 2003). Damage to visual regions involved in visual memory also interferes with long-term autobiographical memory, as these memories rely on an individual's ability to utilize visual imagery (Greenberg & Rubin, 2003). Finally, the frontal lobes are involved in search for relevant information and inhibition of irrelevant information (Greenberg & Rubin, 2003; Levine, 2004; Piolino et al., 2003).

Neuroimaging research has demonstrated that activity in lateral PFC is associated with controlled retrieval processes (Conway et al., 1999), while medial PFC activity is connected to self-referential processing (Botzung, Denkova, Ciuciu, Scheiber, & Manning, 2008; Maquire & Mummery, 1999) and automatic monitoring processes (feeling-of-rightness; Gilboa, 2004). Within the MTL, the hippocampus and surrounding cortical regions are engaged during the recollection of memory details (Botzung et al. 2008; Daselaar et al., 2008; Addis, Moscovitch, Crawley, & McAndrews, 2004b; Cabeza et al., 2004; Maquire & Mummery, 1999). The amygdala is also engaged when individuals retrieve emotional memory details (Cabeza et al. 2004; Daselaar et al. 2008; Fink et al., 1996). Finally, recent research has highlighted the importance of the visual cortex during the visual imagery component of autobiographical memory retrieval (Daselaar et al. 2008; Greenberg, Eacott, Brechin, & Rubin, 2005).

Neural Correlates of Specific Autobiographical Memories

Several neuropsychological studies have implicated the prefrontal cortex in the sense of reliving associated with specific autobiographical memory retrieval (Levine et al., 1998; Levine, 2004; Piolino et al., 2003). Piolino and colleagues (2003) examined autobiographical memory retrieval in patients with damage to frontal lobes. These patients exhibited generalized deficits in episodic autobiographical memory retrieval (i.e., impairment in retrieval of events of all ages). In one recent review, Levine (2004) compared patients with focal frontal damage in two distinct regions. This research demonstrated that patients with ventral PFC (vPFC) and dorsolateral PFC (dlPFC) damage exhibit differing patterns of impaired retrieval. Although vPFC patients retrieved the same number of external autobiographical details as age-matched controls, their memories included significantly fewer internal details. Patients with dlPFC damage exhibit the opposite pattern, an equivalent number of internal details with an increased number of external details, suggesting an underlying impairment in inhibition. Of note, providing retrieval support to patients with dlPFC damage had the effect of significantly increasing production of semantic and irrelevant information relative to healthy young adults (Levine et al., 2002; Levine, 2004). Providing the same support to patients with vPFC damage equated their performance with healthy controls (Levine, 2004).

Several studies have employed functional neuroimaging methods to investigate the neural correlates of specific, relative to general, autobiographical memory retrieval in young adults. Many of these studies have reported increased dorsolateral and medial prefrontal (mPFC) activity during retrieval of specific autobiographical information (Ford, Addis, & Giovanello, 2011; Maguire & Mummery, 1999), suggesting that the prefrontal cortex may be essential for successful retrieval of a specific autobiographical memory. Increased activity was also identified in MTL regions (Ford et al., 2011; Holland, Tamir, & Kensinger, 2010; Levine et al., 2004; Maguire & Mummery, 1999), and visual regions such as the precuneus (Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004a; Holland & Kensinger, 2010) and retrosplenial cortex (Levine et al., 2004).

Age-related anatomical changes may influence which regions are recruited by older adults. Previous studies have shown that the dlPFC is involved in specific memory retrieval in young adults (Ford, Addis, & Giovanello, 2011; Levine et al., 2004; Maguire & Mummery, 1999), but the lateral prefrontal regions are particularly susceptible to age-related structural changes, with the greatest decreases in volume (Haug & Eggers, 1991; Salat, Kaye, & Janowsky, 2001; Tisserand et al., 2002). As such, it may be possible that different anatomical structures, such as the mPFC, support the retrieval of specific memories in older adults. Additionally, it has been well established that older adults recruit brain regions bilaterally during cognitive tasks whereas young adults only engage one hemisphere (Cabeza, 2002). This reduced laterality has been observed in the PFC, as well as in the MTL (Maguire & Frith, 2003). The current study examined whether young and older adults recruited the same regions when successfully retrieving a specific autobiographical memory, or if older adults compensate for age-related changes by recruiting more, or different, neural regions compared to young adults.

Neural Correlates of Emotional Autobiographical Memories

Retrieval of emotional autobiographical memories is supported by the same extended network as neutral autobiographical memories, but is associated with increased activity in the amygdala and mPFC (Fink et al., 1996). Research with young adults suggests that the medial prefrontal cortex plays an important role in regulating emotion (LeDoux, 2000; Ochsner & Gross, 2005; Phan, Wager, Taylor, & Liberzon, 2002) and in the rapid, intuitive, pre-conscious process of monitoring autobiographical memories (Cabeza & St. Jacques, 2007). In addition, Brodmann area 10 (a region of mPFC) is specifically associated with self-referential processing in cognitive tasks, including autobiographical memory retrieval (Amodio & Frith, 2006; Cabeza & St. Jacques, 2007). It has been suggested that the mPFC regulates the amygdala based on the current meaning of the emotional information, reducing the emotional intensity associated with the original event (Ledoux, 2000).

Currently, no functional neuroimaging studies have directly examined age-related differences between emotional and neutral autobiographical memories. However, a number of studies have examined the neural correlates of episodic emotional memory in young and older adults (see St Jacques, Bessette-Symons, & Cabeza, 2009 for review). Importantly, the review by St. Jacques et al., 2009 focused on studies in which participants viewed emotional stimuli and emotional processes at *encoding* was assessed, as only one study has examined the neural correlates of emotional *retrieval* in older adults (Murty et al., 2009). The authors noted that, across studies, healthy aging was associated with an increase in PFC activity and a decrease in amygdala activity (*Fronto-amygdalar Age-related Differences in Emotion* or FADE; St. Jacques et al., 2009). Although increases in PFC activity were consistent across studies, decreases in amygdala activity depended on emotional intensity and task demands. As such, St. Jacques and colleagues (2009) focused on age-related changes in the mPFC during emotional memory.

The precise role of the mPFC during emotional memory has been the subject of several recent studies. Leclerc and Kensinger (2008) observed that older adults recruited mPFC regions to a greater extent for positive relative to negative words, whereas young adults recruited the same region to a greater extent for negative relative to positive words. It has been proposed that the increase in mPFC activation may reveal an increase in self-referential processing when encoding information (Kensinger & Leclerc, 2009). Therefore, self-referential processes may serve as a form of emotional regulation, where positive information receives additional processing for older, relative to young, adults.

A second study utilized effective connectivity methods and revealed a regulatory function of the mPFC on medial temporal lobe regions. Addis and colleagues (2010) demonstrated age-related changes in effective connectivity during encoding of positive stimuli. In older adults, hippocampal activity was modulated by activity in the amygdala and mPFC, suggesting that mnemonic processing, as indexed by hippocampal activity, may receive a boost from mPFC activity in older adults. Conversely, hippocampal activity in young adults was negatively influenced by the amygdala and mPFC, possibly revealing decreases in mnemonic processing for positive information. However, this study did not identify age-related changes in connectivity during encoding of negative stimuli, suggesting that young and older adults encode negative information in a similar way, but that older adults demonstrate increased connectivity for positive information.

The current study was designed to examine age-related changes in the neural correlates during emotional and specific memory retrieval. To date, the underlying neural correlates of these effects have been examined in young adults, but not in older adults. To this end, this study used a novel memory paradigm that elicited highly emotional memories that differed across multiple levels of specificity.

Music as a Retrieval Cue

A novel aspect of the current project was the use of musical cues in the memory paradigm. Music was selected as a retrieval cue for the current experiments for several reasons. It has been demonstrated that retrieval success is higher for musical cues compared to verbal cues (Schulkind & Woldorf, 2005). In other words, participants are able to retrieve more memories when presented with music than when they are presented with words. Importantly, the increase in retrieval success is larger for older relative to younger adults (Schulkind & Woldorf, 2005).This differential increase allows for more equivalent performance between the two groups in the current study.

In recent years, researchers have begun examining retrieval of autobiographical memories using musical cues in behavioral experiments (Cady, Harris, & Knappenberger, 2008; Janata, Tomic, & Rakowski, 2007), as well as in neuroimaging studies (Ford et al., 2011; Ford et al., *under review*-b; Janata, 2009). Previously, I utilized musical cues in an fMRI study with young adults (Ford et al., 2011; Ford et al., *under review*-b). In this study, memories elicited by musical cues were highly emotional (both positive and negative) and spanned multiple levels of specificity. These two characteristics are particularly important for the current project, as I am interested in examining the effects of valence and specificity. Additionally, memories were elicited with limited instructions from the researcher and were rated as relatively unrehearsed by participants. Low levels of rehearsal were important in the current study, allowing the examination of the novel integration of an event, as opposed to a rote repetition of a rehearsed narrative.

Finally, several studies suggest that pathologic age-related memory impairments may be reduced for musical information. One older adult in the severe stages of Alzheimer's disease (Mini-Mental State Exam score of 8/30) had equivalent performance to healthy older adults in tasks of music memory including tune recognition, familiarity judgments, and recall of lyrics (Cuddy & Duffin, 2005). This study suggests that memory for musical information is more resilient than other knowledge. In addition, music has been useful in improving retrieval of unrelated autobiographical material in individuals diagnosed with Alzheimer's disease (Irish et al., 2006). When researchers played familiar classical music in the background during a standard autobiographical memory task, patients showed a significant improvement in retrieval of information from childhood, young adulthood, and recent adulthood (Irish et al. 2006).

Current Study

The current experiments examined age-related changes to autobiographical memory, focusing on how task demands and individual differences in executive control ability influence behavioral patterns and neural correlates of autobiographical retrieval. Experiment 1 focused on the overgenerality and positivity effects as a product of task condition, stimulus type, and executive control ability. This behavioral experiment examined autobiographical memory retrieval in young and older adults with high and low levels of executive control ability, as determined by four measures of executive control processing (inhibition, updating, and two measures of controlled task switching), in three separate autobiographical memory conditions (unrestricted, general, and specific instruction conditions). In addition to subjective judgments of valence and specificity, memory specificity was evaluated based on narrative content, as coded by two independent raters. As indicated previously, music was used as a memory cue in this experiment.

Experiment 2 examined the neural correlates specific and emotional memory retrieval in young and older adults. This functional neuroimaging study utilized one retrieval condition (unrestricted instruction condition) from Experiment 1 to isolate age-related neural differences in retrieval during specific and emotional autobiographical memories. As in Experiment 1, measures of executive control ability were taken to examine the effect of ability on retrieval differences. Together, these experiments systematically investigated the underlying sources, both cognitive and neuroanatomical, of the autobiographical memory changes in the healthy older adult population.

CHAPTER 2: EXPERIMENT 1

Experiment 1employed behavioral methods and had four goals. First, this study was designed to investigate the positivity and overgenerality effects in healthy older adults in three different autobiographical memory conditions. In the first experimental condition, participants were instructed to retrieve *specific* autobiographical memories, whereas in the second experimental condition they were instructed to retrieve *general* autobiographical memories (i.e., the "reversed" memory condition). A third *unrestricted* memory condition was utilized to eliminate age-related differences in autobiographical memory retrieval introduced by task demands. In doing so, this condition highlighted those retrieval differences that exist due to age-related changes in representation, motivational goals, and controlled search process.

In addition, four executive control measures (specifically, measures of inhibition, updating, and two measures of controlled task switching) were collected for each participant, affording the examination of the role of executive control ability in autobiographical memory retrieval. This experiment extended previous research by investigating whether an executive control deficit is related to a decrease in specificity when task demands are reduced (i.e., the unrestricted memory condition). Additionally, this experiment tested the open question as to the role of executive control ability in the positivity effect in older adults' autobiographical memory.

Experiment 1 also examined the interaction between the positivity and overgenerality effects. Previous studies have examined how positive and negative memories differ with respect to detail and specificity (D'Argembeau, Comblain, & Van der Linden, 2003; Ford et al., *under review-a*; Ros et al., 2010; Talarico et al., 2009), but no study has investigated how individual differences in positivity rates correspond to retrieval specificity. The current study compared this relationship in young and older adults.

Finally, Experiment 1 utilized two different measures of memory specificity: Typical specificity ratings, as well as components of Levine's Autobiographical Interview (AI; Levine et al., 2002), an in-depth analysis that dissociates semantic and episodic components of a single narrative. Many previous studies have utilized a summary score of "specificity" to compare memories, but this score has not taken into account the types of details retrieved. To compare the types of details retrieved in young and older adults' specific memories, we included a narrative analysis that followed the procedure outlined by Levine and colleagues (2002).

Methods

Participants

Twenty-five healthy young adults (mean age=18.7, *sd*= .76; mean education= 12.32, *sd*= .63; 10 male) and twenty-one healthy older adults (mean age=75.6, *sd*= 5.97; mean education= 17.14, *sd*= 2.24; 10 male) participated in Experiment 1. One additional young adult (age 18; edu= 12; female) and seven additional older adults (mean age=76.8, *sd*= 9.04; mean education= 15.86, *sd*= 2.34; 1 male) were tested, but were excluded due to task noncompliance. Participants were all right-handed native English speakers without a history of psychiatric illness, neurological disorder, or hearing impairment. Young adult participants were recruited using flyers posted on the UNC campus. Older adults were recruited from the Cognitive Neuroscience of Memory Laboratory database. Young adults received partial course credit for their participation, while older adults were paid for their participation. Before participating in the study, participants gave written informed consent in accord with the requirements of the Institutional Review Board at the University of North Carolina at Chapel Hill.

Materials

Musical Stimuli. Retrieval cues consisted of 30-second musical clips. Music was used to elicit highly emotional memories from various levels of specificity without explicit instruction, allowing for retrieval conditions with fewer task demands. Songs were downloaded from the iTunes music store and converted into WAV files. These clips came from three general categories of songs.

The first two categories consisted of songs that were popular when participants were within the age range of 7 to 21 (2000s for young adults; 1950s for older adults). Presenting young and older adults with age-specific songs provided the opportunity to control for the age of encoding, an important variable to consider when comparing autobiographical memories. Previous research has demonstrated that songs from an individual's youth are remembered best and are associated with greater ratings of emotionality (Schulkind, Hennis, & Rubin, 1999; Schulkind & Woldorf, 2005), making these songs ideal for the current experiment. Of particular importance was that the remote songs act as salient cues for older adults. Because songs were selected based on high public appeal, many of these songs have remained popular over the years. Because we did not test participants on their semantic memory for the name of the song, the artist, or the time period in which the song reached popularity, subsequent exposure to these songs did not contaminate the memory processes of interest. In fact, multiple experiences with a song allowed for a greater variety of events that could be retrieved during the task.

A third category of musical cues consisted of songs from popular movies from the last 20 years. Specifically, these songs were those that were nominated for an Oscar in that time period (1989-2009). This condition served as a direct comparison between groups for memories elicited by the same stimuli. In addition, it allowed us to compare memories encoded at the same time point. In other words, this comparison controlled for the amount of time that has passed since encoding. These songs were pilot tested to ensure equivalent familiarity, valence, and autobiographical saliency in the two age groups.

Executive Control Tasks

Stroop test. The Stroop task (1935; MacLeod, 1991) was used as a measure of an individual's capacity to inhibit irrelevant information. In this task, participants were asked to name the ink color of a stimulus. The stimulus was in the form of a string of X's (neutral trials), the same color word as the color of the ink (e.g. the word "GREEN" in the color green), or a different color word (e.g. the word "RED" in the color green). The measure of inhibition is the difference in retrieval times for the incongruent condition (i.e., the word "RED" in the color green) and the neutral condition (i.e., a string of X's in the color green).

N-back test. The ability to update information that is being held in working memory was tested using an n-back test (Vaughan & Giovanello, 2010; adapted from McElree, 2001). In this task, participants were asked whether or not a current stimulus was identical to the item that was presented N items back (1 or 2). The measure of interest for the current analysis was the accuracy rate for the 2-back task.

Number-Letter task. To measure the capacity to switch from one task to another, we utilized a number-letter paradigm (Rogers & Monsell, 1995). When letter-number pairs were presented in the top half of the screen, participants were required to make an odd/even judgment on the number. When pairs were presented in the bottom half of the screen, participants were required to make consonant/vowel judgments on the letter. All pairs appeared on the bottom for the first part and on the top for the second part, resulting in two "no switch" conditions. The third part was the "switch" condition, with pairs appearing at the top and the bottom. Within the switch condition, switch trials were those in which the prior trial was in the opposite position (e.g., bottom followed by top) and no-switch trials were those in which the prior trial was in the same position (e.g., bottom followed by bottom). There were two measures used in the current analysis: the global task cost and the local cost. The global task-switching cost was calculated by subtracting the retrieval times for the no-switch conditions from the switch condition (i.e., the average RT for part 3 minus the average RT for parts 1 and 2). The local cost was calculated by subtracting the retrieval times for the no-switch trials in part 3 from the switch trials in part 3.

Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). The Beck depression inventory was employed to measure depressive symptoms in young and older adults. The BDI is a 21-item questionnaire resulting in potential scores from 0-63. Each item on the questionnaire corresponds to a specific category of depressive symptom and/or attitude. The BDI was used to ensure that age-related differences in memory retrieval were not caused by higher rates of depressive symptomology in the older adult group.

Picture Description Task. In order to examine age-related differences in linguistic style, participants were asked to complete a picture description task (Gaesser et al., 2010). In this task, participants were presented with fifteen color photographs that depicted people engaged in a particular activity or set of activities for 45 seconds each. Participants were asked to describe the different people, objects, and environment in the picture, as well as their relationship to one another, and were instructed to report only what was literally depicted in the picture without embellishing.

Procedure

Before beginning the experiment, participants engaged in a 30-minute instructional session on the components of autobiographical memory. Specifically, participants learned the three levels of specificity (i.e. personal facts, general memory, and specific memory) described by Conway and colleagues (Conway & Pleydell-Pearce, 2000) and were instructed on the rating scales to be used during the study (i.e. familiarity, memory valence, song valence, and recency). The instruction period familiarized participants about the purpose of the study to ensure that they could effectively rate the qualities and level of each memory.

When participants felt comfortable with the ratings, they began the study. There was a specific memory condition, a general memory condition, and an unrestricted memory paradigm that has been used in our previous research with young adults (Ford et al., 2011; Ford et al., *under review-a*; Ford et al., *under review-b*). Additionally, two lists of songs (i.e., age-specific and movie songs), were included for each instruction condition (i.e., general, specific, and unrestricted) resulting in six lists. The order of these lists was counterbalanced across participants. Each list consisted of 10 experimental trials.

During each memory trial, participants were presented with a 30s music clip and asked to retrieve personal memories associated with the cue, in accordance with the instruction condition (see below). Participants were given 45 seconds to verbally record the event and were asked to identify the level of specificity that best fit their memory by pressing the appropriate button upon retrieval (1=personal facts, 2=general, and 3=specific). Following the musical cue, participants identified the year in which the event took place and rated the memory valence *(1=highly negative, 2=somewhat negative, 3=neutral, 4=somewhat positive, 5=highly positive)*, song valence *(1=highly negative, 2=somewhat negative, 3=neutral, 4=somewhat positive, 5=highly positive)*, and song familiarity *(1=highly unfamiliar/ no familiarity, 2=low familiarity, 3=medium familiarity, 4=high familiarity, 5=very high familiarity)*. Participants had six seconds for each response. After completing the ratings, participants were instructed to prepare for the next trial. Following all six lists of memory retrieval, participants completed the executive control tasks, the BDI, and the picture description task.

Instruction Conditions

Specific Memory Instruction: In the specific memory condition, participants were presented with musical cues and asked to retrieve a *specific* autobiographical memory. Participants were instructed that the memory should be of a single event that occurred over minutes or hours, but no longer than a day, and were given examples of acceptable and unacceptable responses.

General Memory Instruction: In the general memory condition, participants were asked to retrieve a *general* memory associated with the musical cue. General memories were described as being memories of events that extend beyond a single day, either as categories of events (or repeated events) or a single event that extended beyond a single day. Participants were given examples of acceptable and unacceptable responses.

Unrestricted Memory Instruction: In the unrestricted condition, participants were not given explicit instructions as to which level their memory should fit (i.e. specific or general). Instead, participants were reminded of the levels and were encouraged to retrieve whatever memory felt the most natural during retrieval.

Data Analysis

Ratings. Participants' ratings for memory valence and specificity were obtained during the task in order to get online subjective ratings of memory characteristics. In addition, two independent researchers identified one of the following categories for each memory:

- **No memory:** The participant retrieved no autobiographical information.
- **Personal fact:** The participant retrieved autobiographical knowledge or factual information about themselves, but had no memories for any events (e.g., "This song was really popular in junior high.").
- **Repeated event:** The participant had a memory for a cluster of personal events that all belonged to the same category (e.g., "When I was in high school we used to go to the community center for dances on Friday nights.").
- **Extended event:** The participant had a memory for a single event that extended beyond a single day (e.g., "When I was 15 we went on a road trip across the country and we listened to this CD the entire time. This song makes me think of being in the car with my family listening to this type of music.").
- **Specific event:** The participant had a memory for a single event that lasted minutes or hours, but no longer than a day (e.g., "This song reminds me of this one night when I was studying in my dorm and this song was playing. It

was raining and dark and I remember feeling like the song really matched the mood of the night.”).

In addition to having two independent researchers rate the overall level of specificity for each memory, two additional researchers evaluated the narrative content of each memory utilizing the scoring system within the Autobiographical Interview (Levine et al., 2002). The detailed instructions on scoring were meticulously followed in order to accurately replicate previous research performed by Levine and colleagues (2002). Each memory trial was transcribed and segmented into individual details (i.e., a statement that contributed a novel and unique piece of information). Raters scored each memory detail as “internal” or “external”. Internal details were those that were central to a specific retrieved memory, whereas external details were central to general memories or contained semantic or unrelated information. Internal and external details were then categorized based on detail type (e.g. event, time, emotion, perception, and place). These categories allow for a comparison between young and older adults on the type of internal and external details retrieved. Ratings were compared between raters and discussed to achieve agreement. Consistency between raters was evaluated on 60% of these analyses, using an intraclass correlation coefficient (one-way random effects model; McGraw & Wong, 1996). The same scoring system was used to evaluate the proportion of internal and external details in picture descriptions.

Analysis of Variance (ANOVA)

ANOVAs compare average scores across conditions, making them useful for identifying age-related differences, as well as differences across our six task conditions. Self-ratings of song familiarity and song valence were entered into a 3x2x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) and song type (i.e., age-specific and movie songs) as within-subject factors, and age (i.e., young and older adults) as a between-subject factor. Retrieval success was entered in a similar 3x2x2 AONOVA. Due to differences in retrieval success between song types, and our primary interest in age-specific songs, the remaining analyses were conducted for age-specific and movie songs separately using a 3x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) as a within subject factor and age (e., young and older adults) as a between subject factor. Self-ratings of valence, researcher ratings of specificity, and AI scores of narrative specificity were all analyzed using ANOVAs.

Multilevel Model

Although ANOVAs were utilized to compare our between-subject variable (i.e., age), and researcher manipulated within-subject variable (i.e., song type or instruction condition), within-subject variables with item-by-item differences require regression analysis. Due to the clustered structure of the data (i.e. memories are nested within each participant and, therefore, are not statistically independent), classical data analysis methods (e.g., multiple regression) are not appropriate to examine within-subject relationships (Wright, 1998). Specifically, a regression analysis could examine the relationship between retrieval characteristics at the memory level, but would treat each memory as independent, ignoring the similarity between memories within an individual. As such, the model that is the most appropriate for analyzing this type of data is the multilevel model, which can be conceptualized as an extension of multiple regression. The PROC MIXED function was utilized in the Statistical Analysis Software (SAS; http://www.sas.com/) to examine these relationships independently of one another.

The multilevel model can be estimated to include the overall effects of each dependent variable on the independent variable (i.e., fixed effects), as well as variation across participants (i.e., random effects). The current analysis utilized a random intercept model, allowing participants to have varying levels of the dependent variable (e.g., some participants have higher levels of memory specificity), but the relationships between the independent and dependent variables remain constant across participants.

The analysis used two multilevel models to investigate how the internal characteristics of the stimuli (i.e., song valence, familiarity, and the interaction of these variables) altered (a) judgments of memory valence and (b) retrieval of specific memory details (as measured using the AI scoring system). To isolate the within subject effects of the independent variables (i.e., familiarity and song valence), these variables were subject-mean-centered, thereby removing differences between subjects. This mean-centering enabled us to examine how *within* subject differences in familiarity and song valence may influence retrieval characteristics (i.e., valence and specificity) of a particular memory, controlling for potential differences *between* subjects on these variables. In addition, the use of this mixed model design allowed examination of how these relationships might differ based on a between subject factor (i.e., age).

Two additional models examined within-subject relationships between valence and specificity, including age group as a between subject predictor. In the first model, age group and memory valence (and the interaction of the two variables) were used to predict specificity, whereas age group and specificity were used to predict memory valence ratings in the second model. As before, the independent variable in each model was subject-mean-centered. Two final models examined the between-subject relationship between valence and specificity, including age groups as a predictor. In this model, the subject means for the independent variables (i.e., valence and specificity) to directly measure between subject effects. The first between subjects analysis examined individual differences in memory valence (as well as age and the interaction of these values) and how these differences might influence specificity. The second analysis examined how age group, individual differences in specificity, and the interaction of these values influence ratings of memory valence. Although incorporated within the multilevel framework, the between subjects analysis operated the same as standard multiple regression or ANOVA.

Results and Discussion

Initial analysis- Song stimuli

To examine differences in ratings of song familiarity and song valence, all ratings were entered into a 3x2x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) and song type (i.e., age-specific and movie songs) as within subject factors, and age (i.e., young and older adults) as a between subject factor. There was no main effect of instruction condition or age on ratings of familiarity (p=.845 and p=.331 for instruction and age group, respectively) or song valence (p=.901 and p=.598 for instruction and age group, respectively). There was, however, a main effect of song type on both ratings, with age-specific songs being rated as being both more familiar ($F(1.42)=919.697$, $p<.001$) and more positive ($F(1.42)=76.017$, $p<.001$) than movie songs. These results suggest that young and older adults do not generally differ in their ratings and, importantly, task instructions did not influence ratings of the internal characteristics of the stimuli. However, age-specific and movie songs were distinctly different in terms of familiarity and valence.

In examining the interaction effects on ratings of familiarity, all two-way interactions were insignificant. Similarly, the two-way interaction effects of instruction-by-age and instruction-by-song type on ratings of song valence were insignificant. Such findings reveal that age and instruction condition do not generally alter differences in familiarity and song valence across age-specific and movie songs.

The song type-by-age interaction effect on song valence was significant ($F(1,42)= 24.896$, $p<.001$). Follow-up analysis revealed that older adults rated age-specific songs as more positive than young adults ($t(44)=2.542$, $p<.05$), but the two groups had equal ratings for movie songs ($p=.110$). As age-specific songs were particular to each age group, this finding suggests that the difference in ratings may be caused by differences in the song content and not by differences in ratings bias.

In summary, young and older adults did not differ in their ratings of familiarity for either song type. Additionally, young and older adults did not differ in their ratings of song valence for movie songs, but older adults rated age-specific songs as more positive than young adults. Task instructions did not influence ratings of the internal characteristics of the stimuli. Finally, age-specific songs were rated as significantly more familiar and positive than movie songs.

Relationships between song stimuli and memory characteristics

Multilevel models were used to examine the effect that stimuli characteristics had on memory characteristics. The first analysis predicted ratings of memory valence using age group, within subject variations in song valence ratings, and within subject variations in familiarity ratings. In addition, we examined the interactions of these variables. Both song valence and song familiarity had significant effects on ratings of memory valence.

Specifically, a one-unit increase in song valence ratings was associated with a .4-point increase in ratings of memory valence ($p<.001$), and a one-unit increase in familiarity was associated with a .03-point increase in ratings of memory valence ($p<.05$).

Age did not significantly influence memory valence ratings ($p=.25$), but the interactions of age with familiarity and song valence were both significant. The age-by-song valence interaction suggests that the effect of song valence on ratings of memory valence was significantly greater for older adults relative to young adults ($b=.3$, $p<.001$). Of note, this relationship was significant for both young adults ($b= .4$, $p<.001$) and older adults ($b = .7$, $p<.001$; See Figure 1a). The age-by-familiarity interaction also revealed a significantly greater effect in older, relative to young, adults ($b=.05$, $p<.05$). Although this value indicates that the relationship between familiarity and memory valence is .05 larger in older relative to young adults, the relationship was significant in both older adults ($b=.08$, $p< .001$) and young adults ($b= .03$, $p<.05$; See Figure 1b).

A second analysis predicted the proportion of specific details using age group, within-subject variations in song valence ratings, and within subject variations in familiarity ratings, as well as the interactions of these variables. In this analysis, age group was a significant predictor of memory specificity, with older adults retrieving a smaller proportion of specific details in their narratives ($b= -.18$, $p<.001$). Neither song valence nor familiarity significantly predicted specificity ($p=.16$ and $p.23$ for song valence and familiarity, respectively), but the song valence-by-familiarity interaction was a significant predictor ($b=.01$, $p<.01$). This interaction showed that the effect of song valence on memory specificity is .01-point greater for each 1-point increase in song familiarity. Additional investigation of this relationship demonstrated that the relationship between song valence and memory specificity was insignificant at low levels of familiarity (i.e., one standard deviation below the mean; $b = -.01$, $p = .42$) and significant at high levels of familiarity (i.e., one standard deviation above the mean; $b = .03$, $p < .005$ See Figure 2). In other words, when presented with familiar songs, participants retrieved more specific memories for positive songs.

The results described above reveal that song valence and song familiarity were associated with higher ratings of memory valence. Although these relationships were greater in older adults compared to young adults, they were significant for both age groups. Song valence and familiarity did not significantly predict specificity, but the significant interaction suggests that song valence significantly predicts specificity when song familiarity is high. Finally, these analyses demonstrate that age was a significant predictor of specificity, but not memory valence. This finding was further examined in subsequent analyses.

Memory success

Successful retrieval was indexed by the proportion of trials (out of the ten trials in each list) in which participants retrieved autobiographical information, including personal facts, general events, and specific events. This value was entered into a 3x2x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) and song type (i.e., age-specific and movie songs) as within subject factors and age (i.e., young and older adults) as a between subject factor. There was no main effect of instruction condition ($p = .113$) or an interaction of instruction with age group ($p = .815$) or song type ($p = .560$). However, the main effects of song type and age group were significant ($F(1,43) = 39.337$, $p < .001$ and $F(1,43) = 12.291$, $p < .001$, respectively), as was the song type-by-age group interaction ($F(1,43) = 4.959$, $p < .05$). Follow-up analysis revealed that young and older adults were equally successful in retrieving memories for age-specific songs ($p = .06$) but older adults retrieved significantly fewer memories than young adults for movie songs ($F(1,43)= 10.139$, $p<.005$). Additionally, there was a trend for young adults to retrieve more memories for age-specific songs relative to older adults.

A second analysis focused only on memory for autobiographical events (general and specific). In this analysis, the main effects of instruction, song type, and age were all significant ($F(2,86)=3.210$, $p<.05$; $F(1,43)=57.615$, $p<.001$; and $F(1,43)= 51.839$, $p<.001$, respectively). Follow-up analysis revealed that older adults retrieved fewer event memories than young adults in all six memory conditions ($p< .005$) and both young and older adults retrieved more event memories for age-specific relative to movie songs ($F(1,23)=16.587$, $p< .001$) and ($F(1,40)=40.908$, $p<.001$; See Figure 3).

The instruction-by-song type interaction was insignificant ($p=.369$). However, the two-way instruction-by-age and song type-by-age interactions were significant ($F(2,86)= 3.210$, $p< .05$ and $F(1,43)= 5.59$, $p< .05$, respectively). The young adult group retrieved more event memories for the specific instruction condition relative to the unrestricted condition ($F(1,23)= 6.008$, $p<.05$) and the general instruction condition ($F(1,23)= 5.374$, $p <.05$), but these contrasts were insignificant in the older adult group ($p= .115$ for specific relative to unrestricted instruction conditions, and $p=.429$ for specific relative to general instruction conditions). Interestingly, older adults retrieved more event memories in the general event condition relative to the unrestricted condition ($F(1,20)= 5.748$, $p<.05$), but this was not significant in the young adult group ($p=.747$).

These results suggest that there was great variability in the proportion of memory success across our conditions, with participants retrieving more memories for age-specific relative to movie songs, and young adults retrieving more memories than older adults. In order to equate baseline success, subsequent analyses of specific and general memory retrieval in this study take the proportion of specific and general event memories out of the total number of event memories. In addition, as retrieval success was so low for movie songs, the primary analysis focuses on retrieval to age-specific songs.

Effect of task instruction on autobiographical memory specificity

The interrater reliability coefficient for memory specificity ratings was very high (.95), assessed using intraclass correlations (one-way random effects model; McGraw & Wong, 1996). Scores of memory specificity (i.e., proportion of specific memories out of the number of event memories retrieved) for memories of age-specific songs were entered into a 3x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) as a within subject factor and age (i.e., young and older adults) as a between subject factor. The main effect of age was significant, with young adults retrieving more specific memories than older adults ($F(1,43)= 26.28$, $p< .001$). The main effect of instruction was also significant ($F(2,84)= 19.935$, $p< .001$), as was the instruction-by-age group interaction ($F(2,84)= 25.944$, $p< .001$). Follow up analysis revealed that young adults retrieved more specific memories than older adults in the specific instruction condition ($t(43)=8.55$, $p<.001$), but not in the unrestricted condition ($p=.09$) or in the general instruction condition ($p=.469$). Additionally, whereas older adults retrieved the same proportion of specific memories in all three instruction conditions ($p< .2$ for all paired contrasts), young adults retrieved more specific memories in the specific instruction condition relative to the unrestricted condition ($t(23)=6.1$, $p<.001$), and more specific memories in the unrestricted condition relative to the general instruction condition ($t(23)= 3.986$, $p< .001$; See Figure 4a).

The proportion of specific memories retrieved for movie songs was also analyzed using a 3x2 ANOVA. The main effect of age was significant, with young adults retrieving more specific memories than older adults ($F(1,34)= 6.246$, $p< .05$). The main effect of instruction was also significant ($F(2,84)= 15.435$, $p< .001$), but the age-by-instruction interaction in this analysis was not significant ($p=.15$). Although the interaction was insignificant, follow up analyses revealed that young adults retrieved more specific memories than older adults in the specific instruction condition ($t(37)=3.28$, $p<.005$), but not in the unrestricted condition ($p=.30$) or in the general instruction condition ($p=.884$). Additionally, whereas older adults retrieved the same proportion of specific memories in all three instruction conditions ($p<.05$ for all paired contrasts), young adults retrieved more specific memories in the specific instruction condition relative to the unrestricted condition ($t(23)=4.69$, $p<.001$), and an equal proportion of specific memories in the unrestricted condition relative to the general instruction condition ($p=.053$; See Figure 4b).

One final analysis compared the proportion of specific memories in older adults' recent memories (i.e., since 1980) to the proportion in their remote memories (i.e., before 1980). There were not enough memories to examine the differences between separate instruction conditions, so we collapsed across the three instruction conditions. The proportion of specific memories retrieved was not significantly different between recent and remote memories for age-specific ($p=.56$) or movie songs ($p=.29$).

In summary, the overgenerality effect for the specific instruction condition was replicated in the current analysis using musical stimuli. However, this effect was eliminated in the unrestricted and general instruction conditions. This finding suggests that the age-related overgenerality effect is largely driven by older adults' inability to maintain and implement task instructions. Importantly, this same pattern was produced by both age-specific and movie songs, demonstrating that the effect is not a product of our use of age-specific songs. Finally, a direct comparison between recent and remote memories in older adults demonstrated that recency was not associated with specificity.

Effect of task instruction on autobiographical memory specificity- Autobiographical Interview

The interrater reliability coefficient for memory specificity ratings was high (.87). The measure of specificity in this analysis was the proportion of specific (or *internal*) memory details out of the number of details retrieved). Specificity for memories associated with age-specific songs were entered into a 3x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) as a within subject factor and age (i.e., young and older adults) as a between subject factor. The main effect of age was significant, with young adults retrieving more specific details than older adults ($F(1,44)= 55.802$, $p< .001$). The main effect of instruction was also significant ($F(2,88)= 35.692$, $p< .001$), as was the instruction-by-age group interaction ($F(2,88)=36.633$, $p< .001$). Follow up analysis revealed that young adults retrieved more internal details than older adults in the specific instruction condition ($t(34.8)= 8.65$, $p< .001$) and the unrestricted condition ($t(44)=3.619$, $p<.001$), but not in the general instruction condition ($p=.534$). Additionally, whereas older adults retrieved the same proportion of specific details in all three instruction conditions ($p<.4$ for all paired contrasts), young adults retrieved more specific details in the specific instruction condition relative to the unrestricted condition ($t(24)=5.9$, $p<.001$), and more specific memories in the unrestricted condition relative to the general instruction condition ($t(24)= 4.889$, $p< .001$; See Figure 5a).

The proportion of internal details in memories retrieved for movie songs were also analyzed using a 3x2 ANOVA. The main effect of age was significant, with young adults retrieving more specific memories than older adults ($F(1,44) = 29.069$, $p < .001$). The main effect of instruction was also significant ($F(2,88) = 18.117$, $p < .001$), as was the age-by-instruction interaction ($F(2,88) = 11.748$, $p < .001$). Follow up analyses revealed that young adults retrieved more specific details in the specific instruction condition relative to the unrestricted condition ($t(24) = 4.41$, $p < .001$), and more internal details in the unrestricted condition relative to the general instruction condition ($t(24) = 2.348$, $p < .05$). Older adults, on the other hand, retrieved an equivalent proportion of internal details in all three instruction conditions ($p > .05$ for all contrasts, See Figure 5b).

The autobiographical interview scoring system was also used to directly examine differences across subtypes of external and internal details. This analysis compared the proportion of details belonging to detail subtypes (out of the total number of details provided) between young and older adults. This comparison was conducted collapsing across song types and instruction conditions. Relative to older adults, young adults retrieved a greater proportion of internal event ($t(44) = 5.59$, $p < .001$), place ($t(42.7) = 4.355$, $p < .001$), time ($t(44) = 2.69$, $p < .05$), perception ($t(28.2) = 5.24$, $p < .001$), and emotion details ($t(27.4) = 4.94$, $p < .001$). Young adults also retrieved a greater proportion of external event ($t(44) = 6.26$, $p < .001$), place ($t(44) = 2.137$, $p < .05$), time ($t(44) = 3.697$, $p < .001$), perception ($t(24.3) = 4.59$, $p < .001$), and emotion details ($t(44) = 3.144$, $p < .005$), as well as repetitions of previously stated details ($t(30.11) = 6.79$, $p < .001$). These details are central to general autobiographical events, suggesting that young adults retrieve more details than older adults for both general and specific memories. Compared to young adults, older adults reported more semantic details ($t(24.04)= 3.113$, $p< .005$) and information classified as "other" (e.g., metacognitive statements; $t(44)=10.373$, $p<.001$; See Figure 6).

The results of our Autobiographical Interview analysis largely replicate our findings using ratings of memory specificity. However, where we found no overgenerality effect in the specificity ratings analysis for the unrestricted instruction condition, older adults retrieved significantly fewer specific details than young adults in this condition. This finding suggests that some additional differences may exist in the underlying memory representation during the elaboration phase, and that these are highlighted using the Autobiographical Interview scoring system. Importantly, the analysis of detail subtype demonstrates that young adults retrieve more details for specific events, as well as general events, and older adults report more semantic details and metacognitive statements.

Autobiographical interview of picture description task

Participants' picture descriptions were coded along with their memories using the scoring system in the Autobiographical Interview (Levine et al., 2002). Unlike in the memory analysis, young and older adults received an equal proportion of internal ($p= .135$) and external ($p= .238$) details. Examination of the raw number of internal and external details further confirmed that there were no age-related differences in their descriptions ($p=.258$ and $p=.486$ for internal and external, respectively).

Effect of task instruction on autobiographical memory positivity

Average valence ratings for memories elicited by age-specific songs were entered into a 3x2 ANOVA with instruction (i.e., specific, general, and unrestricted conditions) as a within subject factor and age (i.e., young and older adults) as a between-subject factor. The main effects of age and instruction were insignificant ($p= .628$ and $p= .424$, respectively), as was the instruction-by-age interaction (p= .124). A second analysis was performed examining valence ratings for memories retrieved for movie songs. As in the prior analysis, the instruction condition effect was insignificant (p= .697) as was the instruction-by-age interaction (p= .128). However, in the analysis of memories elicited by movie songs, the age effect was significant ($F(1,44)=5.806$, $p<.05$), with young adults rating their movie song memories as more positive than older adults.

Due to age-related differences in memory specificity, it was important to examine differences in valence ratings separately for general and specific autobiographical memories. For general autobiographical memories, there was no age-related difference in valence ratings for either age-specific (p= .173) or movie song memories (p= .939). Similarly, ratings of valence for specific autobiographical memories were equivalent for young and older adults for age-specific (p= .479) and movie song memories (p= .440). An additional analysis demonstrated that valence ratings were equivalent for older adults' recent and remote memories for both age-specific (p=.887) and movie songs (p=.479).

No positivity effect was identified in this analysis, with young and older adults retrieving the same proportion of positive memories for age-specific songs, and young adults retrieving more positive events for movie songs. Additionally, the positivity effect was not influenced by instruction condition, memory specificity, or recency. As the positivity effect is not a robust finding in the autobiographical memory literature, it is not surprising that we found no valence differences. In addition, the lack of an effect might have been caused by a number of methodological issues, such as the number of memories, cuing method, or the emotional quality of the stimuli.

Relationship between autobiographical memory positivity and specificity

Multilevel models were used to examine the relationship between memory positivity and specificity. The first two models focused on within-subject relationships, with within-subject differences in positivity predicting specificity and within-subject differences in specificity predicting valence, using age group as a between subject predictor. Specificity, age group, and the age-by-specificity interaction were all insignificant predictors of memory valence ratings (p>.3 for all contrasts). Similarly, item-by-item differences in memory valence ratings and the valence-by-age interaction were insignificant predictors of specificity (p>.6 for both contrasts). However, age was a significant predictor (b= .20, p<. 001), with young adults retrieving a greater proportion of specific details relative to older adults.

Between-subject relationships between positivity and specificity were also insignificant. Specifically, the average specificity rating for an individual did not significantly predict memory valence (p= .6), and the average valence rating did not predict specificity (p= .13). Age was a significant predictor of specificity (b= -.18, p<.05), but not memory valence (p= .21).

Between-subject and within-subject relationships between valence and specificity were all insignificant. Additionally, this relationship did not differ based on age. It is likely that no relationship existed due to the high ratings of memory valence in both groups.

The effect of executive control ability on autobiographical memory specificity and positivity

To determine how individual differences in executive control ability influence retrieval of autobiographical events, we investigated the relationship between the four executive control measures (i.e., inhibition, updating/working memory, local task-switching cost, and global task-switching cost) and the retrieval of autobiographical events during all six memory conditions. Of note, young and older adults performed equivalently on all four executive control measures (p= .051, p= .064, p= .852, and p= .846 for inhibition, working memory, local task-switching costs, and global task-switching costs, respectively), although there are trends toward young adults having reduced inhibition and working memory impairments. Young and older adults were also equivalent on a measure of depression (the BDI; p=.215; See Table 1).

When using an uncorrected p-value for our correlations (p<.05), high accuracy on the working memory task (i.e., the 2-back task) was significantly associated with increased retrieval of autobiographical events in the general instruction condition for age-specific songs (r= .428, p<.005), in the unrestricted instruction condition for movie songs (r= .316, p<.05), and in the specific instruction condition for both song types (r= .425, p<.005 and r= .380, p<.05 for age-specific and movie songs, respectively). Working memory accuracy also significantly predicted positivity in the general instruction condition to age-specific songs (r= -.320, p<.05) and specificity in the specific instruction condition to age-specific songs (r= .311, p< .05). Reduced difficulty with inhibition (i.e., smaller difference between the RT for the incongruent Stroop and the neutral Stroop condition) was associated with increased retrieval of autobiographical events in both the specific (r= -.315, p< .05) and general (r= -.425, p< .005) instruction conditions for age-specific songs. Finally, increased global task-switching costs (i.e., larger RT for task-switching condition relative to the no-switch condition) was associated with increased positivity unrestricted instruction condition for movie songs (r=.352, p< .05).

When using the Benjamini-Hochberg procedure for correcting for multiple comparisons (Thissen, Steinberg, & Kuang, 2002; Williams, Jones, & Tukey, 1999), only one of these relationships reached significance. High accuracy on the working memory task (i.e., the 2-back task) was significantly associated with more autobiographical events (both general and specific added together) in the unrestricted instruction condition for age-specific songs (r= .521; p< .001). Depression scores were also unrelated to memory event retrieval, memory specificity, and memory positivity, with no correlations reaching significance.

Young and older adults did not differ on any measures of executive control or depression. In addition, the only relationship that reached our corrected threshold was an increased number of event memories in individuals predicted by better working memory accuracy. This relationship suggests that decreased working memory impairs an individual's ability to retrieve memories of any events, regardless of specificity.

Summary

Experiment 1 examined the cognitive and neural mechanisms underlying age-related changes in autobiographical memory retrieval using music cures. Ratings of song valence and familiarity for movie songs were equivalent for young and older adults, as were ratings of familiarity for age-specific songs. However, older adults rated their songs as more positive than young adults. This difference will be particularly important in studies that identify a positivity effect in memory retrieval. While the overgenerality effect was observed using musical cues, the positivity effect was not.

To isolate underlying differences in memory representation, Experiment 1 utilized an autobiographical memory paradigm in which task instructions were manipulated to separate age-related differences in underlying representations from the ability to follow task instructions. In the *general* instruction condition, young adults inhibited retrieval of specific memory whereas older adults did not, resulting in equivalent ratings of specificity in the two groups. The overgenerality effect was significantly smaller in the unrestricted condition relative to the specific instruction condition. However, there were still substantial age-related differences in the unrestricted instruction condition. In particular, young adults retrieved significantly more internal details compared to older adults. In addition, young adults retrieved more external details associated with general events, suggesting that older adults retrieve more details, regardless of overall level of specificity. Older adults, on the other hand, reported more semantic information.

Young and older adults performed equivalently on the picture descriptions task, depression scale, and all four measures of executive control. Additionally, none of these measures contributed to specificity and positivity in autobiographical memory retrieval. Measures of specificity and positivity were not related to one another at the within-subject level (i.e., ratings of specificity and positivity for individual memories) or at the between-subject level (i.e., average ratings of specific and positivity for a given participant).

Experiment 1 investigated the cognitive mechanisms underlying the positivity and overgenerality effects. Specifically, it examined circumstances under which these age-related differences were exaggerated and diminished. Experiment 2 extended these findings by examining age-related differences in neural recruitment when young and older adults successfully retrieve positive and specific memories.

CHAPTER 3: EXPERIMENT 2

The second experiment in the current project examined age-related differences in the neural correlates of emotion and specific memory retrieval using functional magnetic resonance imaging (fMRI) methods. Young and older adults were tested using the unrestricted instruction condition adapted for the scanner environment. Additionally, this experiment used age-specific songs only. This experiment extended previous research by identifying how the neural networks involved in autobiographical memory retrieval change in healthy aging.

Methods

Participants

Sixteen healthy young adults (mean age= 21.75, *sd*= 3.02; mean education= 15.0, *sd*= 2.56; 8 male) and eighteen healthy older adults (mean age= 69.67, *sd*= 7.0; mean education= 17.67, *sd*= 2.35; 5 male) participated in the current study. Three additional older adults (mean age=77, *sd*= 10.1; mean education= 14.0, *sd*= 3.0; 3 female) were tested, but excluded due to task noncompliance. None of the participants from Experiment 1 participated in Experiment 2. Participants were all right-handed native English speakers without a history of psychiatric illness, neurological disorder, or hearing impairment. Young adults were recruited using flyers posted on the UNC campus. Older adults were recruited from the Cognitive Neuroscience of Memory Laboratory database. All participants were paid for their participation. Before participating in the study, participants gave written informed consent in accordance with the requirements of the Institutional Review Board at the University of North Carolina at Chapel Hill.

Materials and Procedure

The stimuli and procedures from Experiment 1 were adapted for use in the scanner for Experiment 2. Before engaging in the autobiographical memory task, participants completed the executive control tasks and picture description task described in Experiment 1. Participants were also given the Geriatric Depression Scale (GDS; Brink et al., 1982; Yesavage & Brink, 1983). Because the BDI did not identify any age-related differences in depressive symptomology in Experiment 1, the GDS was selected as a potentially more sensitive measure for Experiment 2. The GDS was designed specifically for the elderly, carefully considering the unique characteristics of depression in this population (Jarvik, 1976; Wells, 1979).

These tasks were immediately followed by a thirty-minute instruction session on the autobiographical memory task. Participants were then placed in the scanner for the memory task. Although the autobiographical memory task was largely identical to the task described in Experiment 1, there were several changes. First, for the in-scanner task, participants only engaged in unrestricted retrieval for age-specific songs, allowing for an increased number of memories in this condition. In other words, participants never retrieved memories for movie songs or heard specific or general memory instructions. There were also some changes related to the nature of the scanner environment. For instance, stimuli in the scanner were presented using magnet-safe headphones that were selected to minimize distortion of the auditory signal.

In addition, participants did not verbally record memories at the time of initial retrieval. Instead, participants were presented with the 30s music clip and were instructed to retrieve the memory covertly and to hit a button inside the scanner when the memory was retrieved. After hitting the button, each participant spent the rest of the music clip elaborating on the memory as if they were telling the story to another person. At the end of each 30s clip, participants rated memory valence and song familiarity using a 5-point scale (six second each). Memory details were collected later in the post-retrieval interview (see below). Such interviews are standard in fMRI studies examining autobiographical memory retrieval (e.g., Addis et al., 2007; Botzung et al., 2008; Ford et al., 2011).

One final change to the methods described in Experiment 1 was the inclusion of a semantic control task. The semantic task was included to control for neural activity associated with music processing, following task instructions, motor response, and verbal processing. Before each trial, participants were presented with a 2-4 second verbal instruction ("personal" or "adjective") to orient them towards the appropriate retrieval task. To increase the probability that participants do not retrieve personal memories during the control task, highly unfamiliar songs and a fairly difficult control task were chosen.

The songs that were selected for this task were highly unfamiliar songs from popular movies over the last 20 years. These songs were selected from the movie song pilot study for Experiment 1 based on having equally low familiarity and autobiographical salience in both age groups. During the 30-second unfamiliar music clip, participants were asked to select an adjective that described the piece and to provide a definition for the selected adjective. As in the autobiographical memory task, participants were instructed to hit a button once the adjective was selected. Following each trial, participants rated the song familiarity and the difficulty of the control task.

Post-Retrieval Interview. After all four scanned retrieval runs, participants were presented with the musical clips a second time during a recorded post-retrieval interview. During this interview, participants were asked to record each memory exactly as it had been remembered while in the scanner. After recording each memory, participants rated the memory specificity (1= no memory, 2= personal fact, 3= repeated event, 4= extended event, or 5= specific event) and assigned an approximate year for the event. Following the post-retrieval interview, participants were presented with all control stimuli and asked for the adjective selected during the scanned semantic memory task. Additionally, participants identified whether they inadvertently retrieved any autobiographical knowledge during the control task and, if so, the level of specificity of that information. Trials where autobiographical knowledge was retrieved were excluded from analysis.

Data Acquisition

Magnetic resonance images were acquired using a Siemens Trio 3T scanner. Participants' heads were held in place using cushions and a headrest. An initial localizing scan was followed by a high resolution T1-weighted structural scan for anatomical visualization (160 1mm slices, TR=1750ms, TE=4.38ms) and four runs of functional scans collected during memory retrieval. Whole brain, gradient-echo, echo planar images (37 5mm slices, TR=2s, TE=23ms, Flip angle=90) were acquired at an angle perpendicular to the long axis of the hippocampus, identified via the T1 scan.

To present the stimuli in the scanner, magnet-safe headphones were selected that minimized distortion of the auditory signal. Specifically, we pilot tested a set of STAX SR-

003 headphones to ensure that all stimuli could be successfully recognized in the scanner. Scanner safe noise-reducing earmuffs were also used to decrease the amplitude of noise associated with the running scanner. All response data was collected using a magnet-safe button response box.

Preprocessing and Data Analysis

Images were preprocessed and analyzed using SPM8 software implemented in MATLAB (Wellcome Department of Cognitive Neurology, London, UK). Images were co-registered, slice-time corrected, realigned, normalized and smoothed using a Gaussian 8mm kernel. Due to the complexity and length of retrieval, autobiographical memory retrieval typically varies by trial and by individual, resulting in a natural jitter (Addis, Wong, & Schacter, 2007). For the current project, only memory *construction* was examined. This phase was modeled as an event-related response starting 1000ms following cue onset.

Specificity Analysis

The first neuroimaging analysis examined neural differences during retrieval of general and specific autobiographical memories. For each subject, researcher ratings were used to classify each event memory as a repeated event, extended event, or specific event. Extended events were excluded from the analysis, as 56% of participants retrieved zero extended events, and the participants who did have extended events retrieved on average only 1.69. As such, this analysis compared repeated (general) and specific events to the control task.

At the fixed effects level, events were modeled as general (i.e., repeated) autobiographical memories, specific autobiographical memories, or control trials. Paired t-tests were conducted for each subject comparing specific autobiographical events to control trials, and comparing general autobiographical events to control trials. At the random-effects level, the results of these contrasts were entered into separate one-sample t-tests for young and older adults. Two conjunction analyses were conducted to identify those regions in which the difference between memory retrieval trials and the control trials was similar across the two age-groups. These analysis separately examined the conjoined effects in specific memories > control and in general memories > control. To do so, a one-sample t-test for one contrast of interest was computed (e.g., specific memory retrieval > control trials in young adults), and activated voxels from this analysis were used to form a mask. A second one-sample t-test for the other contrast of interest was computed (e.g., specific memory retrieval > control trials in older adults), and the mask from the first analysis was applied, such that the resulting conjunction revealed regions active in both contrasts of interest (e.g. specific > control for young adults and specific > control for older adults). Each of the one-sample t-tests were thresholded at $p < .0225$, resulting in a conjoint voxel-level probability, estimated using Fisher's method (Fisher, 1950; Lazar, Luna, Sweeney, & Eddy, 2002), of $p < .005$.

Two-group independent samples t-tests were used at the random effects level to identify regions in which young and older adults exhibited differential neural responses to autobiographical memory retrieval. For example, the young adult (specific > control) > older adult (specific > control) contrast identified regions in which the difference between specific memory retrieval and control trials was greater for young relative to older adults. The significance threshold for these contrast analyses was set at $p < .005$ (uncorrected) with a ten-voxel extent (Lieberman & Cunningham, 2009).

Emotional Memory Analysis

The second analysis examined neural differences during retrieval of emotional autobiographical memories. At the fixed effects level, autobiographical events were modeled as negative (i.e., valence rating of 1 or 2), neutral (i.e., valence rating of 3), or positive (i.e., valence rating of 4 or 5). Due to a small number of negative events in this analysis (75% of participants retrieved fewer than 5 negative memories), negative and positive events were modeled separately only for visualization purposes (see below). A paired t-test was conducted for each subject comparing neutral autobiographical events to "emotional" autobiographical events (negative and positive events combined together). At the random-effects level, the results of these contrasts were entered into separate one-sample t-tests for young and older adults to identify regions in which activity was greater for emotional relative to neutral autobiographical events. The significance threshold for these analyses was set at $p < .005$ with a ten-voxel extent.

A conjunction analysis was conducted to identify those regions in which the difference between emotional and neutral memory retrieval was similar across the two age-groups. To do so, a one-sample t-test for one contrast of interest was computed (e.g., emotional > neutral memory retrieval in young adults), and activated voxels from this analysis were used to form a mask. A second one-sample t-test for the other contrast of interest was computed (e.g., emotional > neutral memory retrieval in older adults), and the mask from the first analysis was applied, such that the resulting conjunction revealed regions active in both contrasts of interest. Each of the one-sample t-tests were thresholded at $p < .0225$, resulting in a conjoint voxel-level probability, estimated using Fisher's method (Fisher, 1950; Lazar, Luna, Sweeney, & Eddy, 2002), of $p < .005$.

A two-group independent samples t-test was used at the random effects level to identify regions in which young and older adults exhibited differential neural responses to emotional relative to neutral events. For example, the young adult > older adult contrast identified regions in which the difference between emotional and neutral memories was greater for young relative to older adults. Although we did not have a sufficient number of negative memories for direct comparisons between negative and positive autobiographical events, we investigated this relationship visually to determine how positive and negative events contributed to the effect of emotional memory retrieval. To do so, beta weights associated with negative, positive, and neutral autobiographical events were extracted from peak voxels in left superior temporal gyrus and right medial prefrontal cortex for each subject.

Results and Discussion

Behavioral Results

Specific memory analysis

Five healthy older adults were excluded from the specific memory behavioral and neuroimaging analysis for not retrieving any specific memories (mean age= 67.6, *sd*= 6.44; mean education= 18.8, *sd*= 1.3; 2 male). Therefore, the specific memory analysis included all sixteen young adults and thirteen older adults. Young adults retrieved more memories ($t(27)=2.74$, $p<.05$) and more event memories ($t(27)= 4.01$, $p<.001$) than healthy older adults. As in the behavioral analysis, specificity was measured as the proportion of event memories rated as "specific". Young adults retrieved a greater proportion of specific events relative to older adults ($t(27)= 2.88$, $p<.01$). In other words, the overgenerality effect was identified in Experiment 2 using the unrestricted instruction condition[1]. Although this effect was not identified in the unrestricted condition in Experiment 1, the effect approached significance (*p*= .09), suggesting a relationship. It is possible that including four times as many trials in this condition in Experiment 2 led the prior trend to become significant.

Emotional memory analysis

Two young adults (mean age= 18.5, *sd*= .71; mean education= 12, *sd*= 0; 2 female) and three older adults (mean age= 68.75, *sd*= 6.02; mean education= 15.25, *sd*= 2.22; 1 male) were excluded from the emotional memory behavioral and neuroimaging analyses for not retrieving any negative memories. One additional young adult (age=20; education=14; female) was excluded for not retrieving any neutral memories. Therefore, the emotional memory analyses included thirteen healthy young adults and fifteen healthy older adults. Young adults retrieved an average of 4.6 negative memories (*sd*= 3.2), 16.2 positive memories (*sd*= 4.26), and 7.5 neutral memories (*sd*= 3.47). Older adults retrieved an average of 3.8 negative memories (*sd*= 2.94), 16 positive memories (*sd*= 4.17), and 8.2 neutral memories (*sd*= 3.48). As in the behavioral study, ratings between young and older adults did not differ (*p*=.149), replicating the null results found in Experiment 1[2]. This replication strongly suggests that the positivity effect does not exist for memories cued by musical stimuli. Of note, 75% of young adults and 75% of older adults retrieved fewer than five negative autobiographical memories, making it impossible to compare positive and negative

[1] When all young and older adults were included in the behavioral analysis, a significant difference in specificity scores remained (*p*< .001).
[2] When all young and older adults were included in the behavioral analysis, there was still no difference in the mean valence ratings (*p*=.126).

events to one another. As such, negative and positive events were modeled only for visualization purposes.

Executive control measures

To determine how individual differences in executive control ability influence retrieval of autobiographical events, we investigated the relationship between the four executive control measures (i.e., inhibition, updating/working memory, local task-switching cost, and global task-switching cost) and the retrieval of autobiographical events. As in the behavioral study, young and older adults performed equivalently on all four executive control measures (p= .086, p= .36, p= .46, and p= .38 for inhibition, working memory, local task-switching costs, and global task-switching costs, respectively), and on our measure of depression (p= .205; See Table 1). None of these measures significantly predicted memory specificity (p> .3 for all correlations) or ratings of memory valence (p> .1 for all correlations).

These results further confirm that the executive control measures utilized in this project were not related to the memory measures. These null results do not necessary suggest that executive control ability is not required for specific or positive memory retrieval, but rather that the measures we selected do not appropriately tap or engage the executive control processes required for these autobiographical memory tasks. Of note, young and older adults had equal scores on a depression scale specifically designed to identify depressive symptoms in older adults. As such, it is also possible that the older adults tested in this study are higher functioning compared to other samples.

Imaging Results

Neural regions associated with the retrieval of specific autobiographical events

To identify neural regions associated with retrieval of specific autobiographical events, memories rated as "specific" were compared to control trials using individual t-tests at the fixed effects level. At the random-effects level, the results of these t-tests were entered into two separate one-sample t-tests: One for young adults and another for older adults. A conjunction analysis was conducted by creating a mask of voxels where activity was greater for specific events compared to the control condition (significant at $p<.0225$) in the young adult group, and applying this mask to the same older adult contrast (at $p<.0225$), thus identifying regions that were active at the conjoint probability of $p< .005$, estimated using Fisher's method (Fisher, 1950; Lazar, Luna, Sweeney, & Eddy, 2002).

This conjunction analysis revealed that young and older adults recruited many of the same regions during retrieval of specific autobiographical memories compared to the semantic control task. Both groups engaged left ventrolateral cortex (BA 47, BA 45, and BA 44) and the right MTL (amygdala) during retrieval of specific memories. These regions have previously been implicated in the retrieval of specific autobiographical memory retrieval in young adults, suggesting that older adults are capable of recruiting the same regions as young adults to increase the specificity of their memory representations (Ford et al., 2011; Holland, Tamir, & Kensinger, 2010; Levine et al., 2004; Maguire & Mummery, 1999). In addition, both young and older adults recruited both superior and inferior parietal lobes (BA 7, BA 40), regions that have been implicated in successful episodic memory retrieval (Yonelinas et al., 2005).

A two-group t-test compared activity preferentially associated with specific memory retrieval in the two groups (e.g., activity in young adults to a greater extent than in older adults). The results of the individual t-tests (i.e., specific events > control trials) for each subject were entered into a two-group t-test, comparing young and older adults. Compared to older adults, the young adult group preferentially recruited the cuneus (BA 18), fusiform gyrus (BA 37), and precentral gyrus (BA 6), as well as anterior cingulate (BA 24). Older adults engaged right insula (BA 13), and premotor cortex (BA 6; See Table 2 and Figure 7). Interestingly, young adults engaged the right anterior medial PFC (BA 10) to a greater extent than older adults, and older adults recruited left anterior medial PFC (BA 10) more so than young adults. Both right and left BA10 have been associated with retrieval of specific, relative to general autobiographical memory retrieval (Ford et al., 2011), so the difference in laterality was unpredicted.

A second conjunction analysis was conducted to identify regions commonly engaged by young and older adults during general event retrieval. Both young and older adults recruited a network of frontal (BA 9, BA 10) and parietal regions (BA 7, BA 40). Due to extensive activity observed for both groups, a number of large clusters extended into multiple brain regions. The analysis software (SPM) reports only the peak voxels in each cluster, leaving all other regions, some of theoretical significance, unidentified. For instance, visual investigation of common activity suggested that activity in several large clusters extended into the left MTL. To identify peak voxels in this region, we re-ran this analysis, limiting it to bilateral MTL structures. Doing so confirmed our prediction that there was, in fact, common activity in the left MTL. The analysis produced two clusters in the left MTL: One in the left parahippocampal gyrus (entorhinal cortex, -30, 4, -18), and the other in the left hippocampus (-32, -20, -18).

Activity preferentially engaged during general events, relative to control trials, was also compared between young and older adults. Compared to older adults, young adults recruited more visual regions (BA 18, BA17, and BA 19), lateral temporal lobes (BA 22), and left inferior frontal gyrus (BA 47). Older adults relied more heavily on midline structures such as the left anterior medial PFC (BA 10) and left posterior cingulate (BA 31; See Table 3 and Figure 8). These results suggest that, in part, young and older adults rely on distinct cognitive processes during retrieval of general autobiographical events.

Neural regions associated with the retrieval of emotional autobiographical events

To identify neural regions associated with retrieval of emotional autobiographical events, positive and negative events were compared to neutral events. All three event types were modeled separately, but there was an insufficient number of negative events to directly compare negative events to neutral. As such, positive and negative events were combined into "emotional" events and compared to neutral events using individual t-tests at the fixed effects level. At the random-effects level, the results of these t-tests were entered into two separate one-sample t-tests: One for young adults and another for older adults. A conjunction analysis was conducted by creating a mask of voxels where activity was greater for emotional events compared to neutral (significant at $p<.0225$) in the young adult group, and applying this mask to the same contrast in older adults (at $p<.0225$), thus identifying regions that were active at the conjoint probability of $p< .005$. This conjunction analysis revealed that the single region recruited by both young and older adults during retrieval of emotional autobiographical events relative to neutral autobiographical events was the right ventrolateral prefrontal cortex (BA 47; See Table 4 and Figure 9), a region involved in the retrieval of autobiographical memory details (Levine, 2004).

A two-group t-test compared activity preferentially associated with emotional memory retrieval in the two groups (e.g., activity in young adults to a greater extent than in older adults). The results of the individual t-tests (i.e., emotional events > neutral events) for each subject were entered into a two-group t-test, comparing young and older adults. These analyses identified regions preferentially recruited by young versus older adults during emotional memory retrieval. Compared to older adults, young adults relied more heavily on lateral temporal regions (bilateral BA 22 and right BA 41), regions involved in semantic and gist-based processing (Dennis et al., 2008). Visual examination of a peak voxel in left BA 22 revealed that the young adults recruited this region primarily during retrieval of positive, as opposed to negative, emotional events. Young adults also engaged the left ventrolateral prefrontal cortex (BA 47) to a greater extent than older adults during retrieval of emotional relative to neutral event retrieval, suggesting that their emotional autobiographical memory retrieval might rely on increased retrieval of memory details.

Older adults, compared to young adults, recruited right ventromedial prefrontal cortex (BA11) and bilateral visual regions (BA 17, BA 18, BA 19, and BA 37) during retrieval of emotional relative to neutral memories. The ventromedial prefrontal cortex was recently implicated in a review of episodic memory encoding, showing increased activity in older, relative to younger, adults (St. Jacques et al., 2009). Of note, many of the studies reported in that review focused on the comparison of negative to neutral image encoding. As such, we extracted percent signal change from the peak voxel of this ventromedial PFC cluster to present neural activity differences visually. Although it appeared that older adults recruited this region more for both positive and negative autobiographical events relative to neutral events, the effect largely reflects activity during negative event retrieval (See Table 4 and Figure 10).

Summary

The fMRI analyses in Experiment 2 directly compared neural recruitment during specific and emotional memories in young and older adults to determine whether they engage the same netoworks during retrieval. Young and older adults relied on many of the same neural regions when retrieving specific autobiographical memories. These regions included right medial temporal lobe, ventrolateral prefrontal cortex, and both inferior and superior parietal lobes. Additionally, both young and older adults recruited regions within the anterior medial prefrontal cortex. Notably, young adults recruited right mPFC to a greater extent than older adults, and older adults recruited left mPFC to a greater extent than young adults. It is currently unclear why young and older adults would differentially recruit left versus right mPFC for autobiographical memory tasks, as both left and right mPFC are implicated in specific autobiographical memory retrieval (Ford et al., 2011). Although young and older adults relied on a similar neural network, young adults preferentially recruited the cuneus, a region in the occipital lobe involved in visual processing.

During retrieval of general events, young and older adults recruited dorsal frontal regions, inferior and superior parietal lobes, and left MTL. Compared to older adults, young adults preferentially engaged the ventrolateral prefrontal cortex and lateral temporal lobes. Older adults, on the other hand, preferentially recruited the anterior medial prefrontal cortex. Such findings suggest that young and older adults employ distinct cognitive processes during general autobiographical memory retrieval.

Behaviorally, young and older adults retrieved the same number of negative, neutral, and positive autobiographical memories. However, young and older adults recruited distinct neural regions during retrieval of emotional autobiographical memories. Young adults preferentially recruited bilateral lateral temporal lobes. Older adults engaged the ventromedial PFC, the same region identified by Leclerc and Kensinger (2008) as reflecting differential recruitment for young and older adults during incidental encoding of emotional stimuli. Although we were unable to separately compare negative and positive events to neutral events, visual examination of the percent signal change during negative and positive events suggested that the enhanced recruitment of the mPFC in older adults reflected activity during retrieval of negative events. Young adults, on the other hand recruited this region to a similar extent for neutral and negative events.

CHAPTER 4: GENERAL DISCUSSION

The current study examined the cognitive and neural mechanisms underlying age-related changes in autobiographical memory retrieval. Music was selected as a retrieval cue due to its unique capability to elicit specific emotional memories without explicit retrieval instructions. The behavioral results of Experiments 1 and 2 provided information regarding the use of musical cues in the elicitation of autobiographical memories in young and older adults. Although musical cues were not directly compared to verbal cues, the current study suggests that music may be ideally suited to evaluate certain age-related differences at the behavioral and neural levels. To isolate underlying differences in memory representation, Experiment 1 utilized an autobiographical memory paradigm in which task instructions were manipulated to separate age-related differences in underlying representations from the ability to follow task instructions. Three instruction conditions (specific, general, and unrestricted) were compared to determine the extent to which differences in instruction contribute to the overgenerality and positivity effects. Experiment 1 also investigated a number of other factors that could contribute to these effects (i.e., narrative style, depressive symptoms, and executive control ability). Experiment 2 examined age-related differences in neural recruitment during retrieval of emotional and specific autobiographical memories, identifying functional neural differences that may exist in the absence of behavioral differences. The current study serves as an important step in understanding age-related changes in autobiographical memory retrieval and introduces new questions that should be addressed with future research.

The use of musical cues

The current project utilized two types of popular music cues to elicit memories from young and older adults. Songs were selected to be highly familiar in order to increase successful retrieval in both populations. Movie songs were used as a control condition in which both young and older adults retrieved the same songs during the memory task. Ratings of song valence and familiarity for movie songs were equivalent for young and older adults, suggesting that there were no underlying response biases in judgments of song emotion and that young and older adults knew these songs to the same extent.

Age-specific songs were used to elicit memories from participants' adolescent years. Importantly, young and older adults rated their respective age-specific songs as equally familiar, suggesting that these songs were well matched in terms of exposure and prior knowledge. However, older adults rated their songs as more positive than young adults. Equivalent ratings of valence for the movie songs suggested that there was not an overall response bias for older adults. As such, the songs selected for older adults may have been more positive than those selected for young adults. The difference in valence in age-specific songs is important to consider when evaluating age-related changes to memory characteristics. Song valence was not significantly related to memory specificity, so the age-related difference in song valence was not a factor in this effect.

Ratings of song valence, however, did significantly predict memory valence, suggesting that any age-related differences in song valence could lead to age-related differences in memory valence. Had we found age-related difference in memory valence, ratings of song valence would have to be considered as a covariate. If future studies utilizing musical cues *do* identify a positivity effect, song valence must be considered.

Due to low retrieval success in Experiment 1, movie songs were not used in the Experiment 2. However, movie songs were essential to the behavioral study to determine whether the patterns we identified were unique to age-specific songs. The songs selected for the age-specific condition were emotionally connected to a highly significant period in the lives of our participants, potentially altering the retrieval mechanisms. However, the same patterns of specificity and positivity were identified for both song types, suggesting that the unique qualities of age-specific did not influence the retrieval patterns. A second potential confound introduced by the age-specific songs was the difference in recency; older adults' songs are necessarily older than young adults' songs. Movie songs were used to demonstrate that memories for more recent songs result in the same retrieval patterns. Additionally, recent and remote memories were directly compared to confirm that recency was not related to memory characteristics in this study.

The use of musical cues did not alter the standard overgenerality effect in older adults. Additionally, we found that task demands play an important role in the overgenerality effect during retrieval of memories cued by music. Such findings suggest that musical cues may be useful in future studies examining this effect. However, our use of musical cues for autobiographical memory retrieval might have reduced the participants' reliance on executive control processes beyond those required for the maintenance of task instruction. It has been suggested that emotional and salient retrieval cues, such as music, can automatically trigger specific autobiographical memories (Conway & Pleydell-Pearce, 2000; Haque and Conway, 2001). As such, musical cues might have reduced the executive control demands of the actual search process. Although the use of musical cues would not have altered the patterns identified across instruction conditions, it may have increased the overall retrieval of specific memories.

There was no indication of an age-related positivity effect in the behavioral data in either of our experiments. Although all studies do not consistently show a positivity effect in autobiographical memory, there is no general agreement as to which factors contribute to the presence of the effect. It is possible that our use of musical cues contributed to this null effect. It has previously been noted that music is a highly emotional cue that can directly trigger emotional memories from an individual's past. One explanation for the positivity effect is that it is driven by age-related changes in the recruitment of top-down executive control processes used to enhance positive and diminish negative information during memory retrieval (Mather & Carstensen, 2005; Mather & Knight, 2005). According to this research, the positivity effect requires a strategic shift in resources to successfully alter retrieval, making the effect dependent on executive control functioning (Mather & Knight, 2005). As such, a retrieval cue that bypasses the strategic selection of a positive or negative memory may diminish the positivity effect. Consistent with this prediction, the positivity effect was not identified in a recent study using emotional positive and negative cue words (Schlagman et al., 2009).

One recent study identified the positivity effect during involuntary autobiographical memory retrieval (Schlagman et al., 2009), suggesting that the positivity effect might also result from underlying automatic processes. However, Schlagman and colleagues suggest that the primary cause of the positivity effect in their study might have been age-related changes in attention to positive and negative external cues. Older adults may attend to fewer negative items in their environment, thus experiencing fewer automatic memories associated with negative emotions. As the retrieval cues in the current study were experimentally controlled, it is unlikely that differences in attention would alter memory retrieval. As such, it is still probable that the use of more automatic and emotional retrieval cues could reduce the positivity effect.

Musical stimuli were used for their unique ability to successfully evoke autobiographical memories in young and older adults. However, the use of such a salient cue might reduce the generalizability of our results. Future studies are required to determine the extent to which these findings are unique to memories elicited by musical cues. It is possible that musical cues reduce age-related changes by automatically triggering specific and emotional memories. Such a reduction would be valuable for researchers attempting to eliminate the negative changes associated with healthy and pathological aging. In addition, music might be unique in its ability to improve the well-being of healthy older adults as well as those diagnosed with dementia. Previous research has shown that playing music can alleviate the autobiographical memory impairments associated with Alzheimer's disease (Irish et al., 2006). Additionally, new research has used music as part of an elaborate program that attempts to facilitate memory retrieval by immersing older adults in the sights and sounds of their pasts (Langer, 2009). Such research suggests that musical cues may be used to treat the age-related memory losses in typical and pathological aging and, as such, a systematic comparison of the effects of these songs is warranted.

Effects of task demands

The primary purpose of Experiment 1 was to examine the effects of task instruction on the positivity and overgenerality effects in older adults. The standard positivity effect was not identified in either of our experiments and there were no effects of instruction, specificity, or recency on positivity, and no interaction of age with any of these variables. Experiment 1 identified the overgenerality effect to the standard "specific" instruction, as measured by both researcher ratings of specificity, as well as the scores on the Autobiographical Interview coding system. As such, it was possible to further examine the role of instruction condition.

For both ratings of specificity and the AI coding system, instruction condition did not influence older adults' retrieval, suggesting that older adults were not maintaining and implementing task instructions during retrieval. Young adults, on the other hand, had higher scores for specificity in the specific instruction condition relative to the unrestricted instruction condition, and higher scores in the unrestricted condition relative to the general instruction condition. This modulation in retrieval demonstrates that young adults are capability of using the task instruction during retrieval and are willing to alter their memory retrieval processes to match these instructions.

The *general* instruction was developed by Dalgleish and colleagues to evaluate the extent to which difficulty maintaining task instructions contributes to the overgenerality effect in a given population (Dalgleish et al., 2007; Dalgleish et al., 2008). When given the general instruction condition, individuals with high executive control ability inhibit *specific* autobiographical memories, reducing their measures of specificity for that condition. Individuals with low executive control ability do not inhibit specific memories, resulting in the same level of specificity across conditions. In Experiment 1, young adults inhibited retrieval of specific memory whereas older adults did not, resulting in equivalent ratings of specificity in the two groups. In prior research, this has resulted in an *overspecificity effect* in individuals who typically exhibit an *overgenerality effect.* There are two potential explanations for why a full reversal was not seen in our population. First, specific retrieval was very low in older adults. It is possible that this low retrieval approached a floor effect (older adults means ranged from .14-.27 across conditions), making it difficult for young adults to retrieve fewer specific memories in any circumstance. Second, the overgenerality effect in older adults might be more complicated than in populations that have previously been tested with the general instruction condition. In other words, it is possible that additional factors, such as narrative changes or emotional regulation, are contributing to this effect.

The unrestricted instruction condition was included to further examine this possibility by obtaining a measure of the overgenerality effect beyond age-related differences in the ability to maintain and implement task instructions. The overgenerality effect was significantly smaller in this condition relative to the specific instruction condition. However, there were still substantial age-related differences in the unrestricted condition. When comparing researcher ratings of the overall degree of specificity of the memory, young adults retrieved more specific memories than older adults. This difference was significant in Experiment 2, but not in Experiment 1. It is possible that including four times as many trials in this condition in Experiment 2 led the trend in Experiment 1 (p=.09) to reach significance. The scores obtained using the Autobiographical Interview scoring system revealed a substantial age-related difference in the unrestricted condition of Experiment 1. In particular, young adults retrieved significantly more internal details compared to older adults. In addition, young adults retrieved more external details, suggesting that older adults retrieve more details, regardless of overall level of specificity. Older adults, on the other hand, reported more background semantic information.

Other factors contributing to age-related changes in autobiographical memory retrieval

The results detailed above suggest that task demands play a central role in the overgenerality effect, but that there are other underlying mechanisms involved. These differences are more apparent when specificity is measured using the Autobiographical Memory scoring system, suggesting that these mechanisms may involve differences in the elaboration phase of memory retrieval. In other words, whereas young and older adults retrieve memories that are of equal levels of specificity overall, young adults provide more details about these events. Although the current study did not directly compare these other possible mechanisms, a number of measures were included that provide initial insight into the role that they play.

Linguistic style

Gaesser and colleages (2010) recently included a picture description task along with a memory retrieval task to further examine the underlying sources of age-related autobiographical memory impairments. Notably, they found that the typical overgenerality pattern extended to the picture description task. Moreover, performance on this task accounted for a majority of the age-related differences in memory performance. This finding is consistent with research suggesting that age-related changes in autobiographical memory specificity may reflect a change in narrative style and an age-related tendency to incorporate individual events into a single history (Levine, 2004). In other words, older adults may retrieve overly general autobiographical memories due to a more integrative approach to viewing their personal past.

Recent research has examined age-related changes in narrative style and documented that older adults are less likely than young adults to report perceptual or contextual details because changes in focus encourage retrieval of memory gist (Bluck, Levine, & Laulhere, 1999) and the internal thoughts and feelings generated by the event (Comblain, D'Argembeau, & Van der Linden, 2005; Hashtroudi, Johnson, & Chrosniak, 1990). Additionally, the self-defining memories of older adults are more likely to contain integrative meaning than those of young adults (Singer, Rexhaj, and Baddeley, 2007). In addition, when older adults tell stories, they are more likely than young adults to include directive lessons (McAdams, St. Aubin, & Logan, 1993; Pratt, Norris, Arnold, & Filyer, 1999) and elaborations with evaluative and interpretive meaning (Gould, Trevithick, & Dixon, 1991; Hashtroudi, Johnson, & Chrosniak, 1990). It has been suggested that this very ability to rely on broader, time-independent knowledge structures may give rise to increased wisdom in the older adult population (Labouvie-Vief & Blanchard-Fields, 1982).

In the current study, we used an adapted version of the picture description task and did not identify any age-related differences in detail retrieval. Methodological differences might have contributed to this different pattern of results. Importantly, Gaesser and colleagues (2010) utilized the interview portion of the AI, including general prompts that were given to participants to solicit further details. These prompts encouraged participants to retrieve additional information when they finished spontaneously reporting picture details. The use of the AI in their picture task reflected the use of these same retrieval prompts in their memory task.

The picture description task was used in the current study to determine the extent to which age-related linguistic and narrative changes contributed to the overgenerality effect in healthy aging. As such, the methods in the picture description task were designed to match those in our memory task. General prompts were not utilized throughout the memory and picture description tasks in the current study due an interest in more natural retrieval processes. In other words, we were interested in the number of types of details that were spontaneously retrieved by young and older adults. It is possible that the general prompts utilized by Gaesser and colleagues (2010) helped young adults report more information than older adults, thereby resulting in an age-related difference in the number of internal details reported. Additionally, pilot testing for the current project showed that participants needed only 45 seconds to finish reporting details when only spontaneous reports were collected. A longer reporting time might have also given young adults a greater advantage in the picture task, enhancing the age effect. The results of the current study suggest that the picture description task might be the ideal tool for capturing age-related linguistic differences when the full Autobiographical Interview is used, but not for studies examining spontaneous retrieval of details.

Although the picture description task did not reveal age-related linguistic differences in our sample, data from the memory task suggest shifts in narrative style. Specifically, young adults consistently reported more details for both specific and general autobiographical events, whereas older adults reported more semantic facts and made more metacognitive statements. Such findings suggest that age-related linguistic differences might exist that were not captured by our picture description task. Future research is required to identify an appropriate procedure to measure these differences.

Depression

Recent research has demonstrated that depressed older adults exhibit a greater overgenerality effect than non-depressed older adults (Birch & Davidson, 2007; Serrano, Latorre, & Gatz, 2007). Similarly, the positivity effect is stronger in non-depressed relative to depressed older adults (Serrano, Latorre, & Gatz, 2007). As depression has been cited as a major problem facing older adults, with an estimated prevalence of approximately 33% (Cole, Bellavance, & Mansour, 1999), depressive symptoms were important to consider in the current study when examining age-related differences in overgenerality and positivity.

Experiment 1 used Beck's Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), a 21-item self-report questionnaire resulting in potential scores from 0-63. Each item on the questionnaire corresponded to a specific category of depressive symptom and/or attitude. Young and older adults were equivalent on the BDI score, leading to our decision to utilize the Geriatric Depression Scale (GDS; Brink et al., 1982; Yesavage & Brink, 1983) in Experiment 2. The GDS was selected because it is reported to be a more sensitive measure of depressive symptoms in older adults, being designed specifically for the elderly (1981; Jarvik, 1976; Wells, 1979). Despite using this sensitive measure, young and older adults had equal scores on the GDS in Experiment 2. These results suggest that our sample of older adults did not have elevated levels of depressive symptoms compared to our young adults. Therefore, depressive symptoms were not a likely contributing factor in the overgenerality effect in our sample.

Executive control

Recent research has revealed that increases in executive control ability correspond to decreases in overgeneral autobiographical memory (Addis et al., 2008; Birch & Davidson, 2007; Piolino et al., 2010; Ros et al., 2010) and increases in the positivity effect in episodic memory (Mather & Knight, 2005). However, prior studies did not examine these relationships during memory retrieval for the unrestricted instruction condition. To investigate these relationships, the current study included four measures of executive control ability: Inhibition (the Stroop), updating/working memory (an n-back task), and a local task switching and global task switching costs (a number-letter task).

Inhibition indices and both measures of task-switching costs (i.e., local and global) were not related to any measures of memory retrieval (i.e., success, specificity, and positivity). Increased working memory, as measured by accuracy rates on the 2-back task, was significantly associated with retrieval of more autobiographical events (both general and specific) in the unrestricted instruction condition. Importantly, this relationship suggests that working memory ability is required to retrieve all autobiographical events, regardless of instruction or level of specificity. This is consistent with the theory that executive control processes are involved in the iterative search process through autobiographical knowledge (Conway and Pleydell-Pearce, 2000). This finding suggests that individuals with lower working memory capability might have trouble searching for and selecting personal events related to a retrieval cue.

It is notable that none of our executive control measures were related to memory specificity or positivity, as has been reported previously (Addis et al., 2008; Birch & Davidson, 2007; Piolino et al., 2010; Ros et al., 2010; Mather & Knight, 2005). These null results do not necessary suggest that executive control ability is not required for specific or positive memory retrieval, but rather that the measures we selected do not appropriately represent the executive control processes required for these tasks. Our measures were selected based on prior studies that have identified these relationships during memory tasks that utilize verbal cues. If music automatically triggers autobiographical memories (Conway & Pleydell-Pearce, 2000; Haque and Conway, 2001), the memories retrieved by young and older adults might involve more automatic processes. It is possible that retrieval of memories associated with musical cues relies on distinct executive control processes that are not reflected in the executive control measures utilized in this project.

A second methodological issue that may have impacted our results was small sample size. Several of these prior studies had substantially larger sample sizes compared to our two experiments (*n*= 46 for Exp. 1; *n*=34 for Exp. 2). Piolino and colleagues (2010) had 50 young and adults and 50 older adults, Ros and colleagues (2010) had 46 older adults, and Mather and Knight (2005) had 31 older adults and 25 young adults. Given our smaller samples, it is possible that our null results reflect low power. However, two studies found significant relationships between specificity and executive control measures with only seventeen participants per age group (Addis et al., 2008; Birch & Davidson, 2007). Such findings suggest these relationships should be identifiable with our small sample sizes. In addition, a secondary analysis was conducted that examined the relationship between executive control ability and memory characteristics in all of our subjects, collapsed across both experiments (*n*= 80). Even with this larger sample, none of the executive control measures were significantly associated with memory specificity or positivity.

Neural correlates of autobiographical memory retrieval

Experiment 1 examined the circumstances under which age-related differences in autobiographical memory do, and do not, exist. Experiment 2 focused on identifying age-related differences in neural recruitment under those circumstances in which young and older adults retrieve memories with the same levels of specificity and positivity. Such analyses are important when considering whether young and older adults rely on the same underlying cognitive processes during retrieval of the same type of information.

Neural correlates of specific autobiographical memory retrieval

In both experiments, young adults retrieved more specific memories than older adults. The fMRI analysis in Experiment 2 directly compared neural recruitment during these memories to determine whether young and older adults engaged the same regions when specific memories were retrieved. Young and older adults relied on many of the same neural regions when retrieving specific autobiographical memories. These regions included right medial temporal lobe, ventrolateral prefrontal cortex, and both inferior and superior parietal lobes. The ventrolateral prefrontal cortex and the medial temporal lobes have previously been implicated in the retrieval of specific, relative to general, autobiographical memories in young adults (Ford et al., 2011; Holland, Tamir, & Kensinger, 2010; Levine et al., 2004; Maguire & Mummery, 1999), suggesting that both young and older adults were able to recruit these regions to enhance the specificity of their memory representation. Additionally, Levine (2004) demonstrated that damage to the ventral prefrontal cortex was associated with reductions in retrieval of internal memory details. As such, engagement of this region during retrieval of specific memories might reflect the retrieval of multiple memory details in both young and older adults.

Specific autobiographical memory retrieval was also associated with increased recruitment of bilateral inferior (BA 40) and superior (BA 7) parietal regions. Although these regions have not been systematically investigated in autobiographical memory studies, they have been implicated in successful episodic memory retrieval (Yonelinas et al., 2005).

Inferior parietal regions have been associated with recollective memory processes, whereas superior regions have been implicated in familiarity-based processes (Yonelinas et al., 2005). Our results suggest that both young and older adults are able to rely on both mnemonic processes during retrieval of specific autobiographical memories.

Finally, both young and older adults recruited regions within the anterior medial prefrontal cortex (BA 10). Bilateral activity in Brodmann area 10 has been highlighted as a key region in autobiographical memory monitoring (Cabeza & St. Jacques, 2007) and self-referential processing (Amodio & Frith, 2006). Additionally, increased activity in bilateral BA10 has been associated with retrieval of specific, relative to general autobiographical memory retrieval (Ford et al., 2011). Notably, young adults recruited right mPFC to a greater extent than older adults, and older adults recruited left mPFC to a greater extent than young adults. It is currently unclear why young and older adults would differentially recruit left versus right mPFC for autobiographical memory tasks, but the recruitment of this region in both age groups suggests that all participants likely employ self-referential processing during retrieval of specific memories.

Although both age groups relied on a similar neural network, young adults preferentially recruited the cuneus, a region in the occipital lobe involved in visual processing. Visual regions have previously been implicated as contributing to increased specificity in memory retrieval (Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004; Holland & Kensinger, 2010; Levine et al., 2004). Age-related reductions in visual regions are common and a component of the well-documented *Posterior to Anterior Shift in Aging* (PASA; Davis et al., 2008).

The results of Experiment 2 suggest that young and older adults primarily rely on the same neural regions during retrieval of a specific autobiographical memory. Such findings suggest that the same cognitive processes are involved in young and older adults' specific autobiographical memory retrieval, despite young adults' increased retrieval of these events. General event retrieval, on the other hand, was associated with recruitment of different neural regions in young and older adults. Compared to older adults, young adults preferentially recruited the ventrolateral prefrontal cortex and lateral temporal lobes. Lateral temporal lobes have been associated with gist-based processing in memory retrieval, suggesting that young adults rely on semantic knowledge during general autobiographical memory retrieval (Dennis et al., 2008). Older adults, on the other hand, preferentially recruited the anterior medial prefrontal cortex (BA 10). This finding suggests that older adults rely more heavily on self-referential knowledge during retrieval of general autobiographical memories.

Importantly, the unique qualities of our musical stimuli might have contributed to the overlap in neural recruitment and cognitive processes during specific memory retrieval. Specifically, because these cues were so salient, the elicited specific events might have been particularly vivid for both young and older adults. It is possible that retrieval of specific events elicited by verbal cues might be associated with distinct neural networks in young and older adults. Future research is required to determine whether musical cues reduce age-related differences in neural recruitment during autobiographical memory tasks.

Neural correlates of emotional autobiographical memory retrieval

Behaviorally, young and older adults recruited the same number of negative, neutral, and positive autobiographical memories. However, young and older adults recruited distinct neural regions during retrieval of emotional autobiographical memories. Young adults preferentially recruited lateral temporal lobes, whereas older adults recruited the ventromedial PFC (BA11), the same region identified by Leclerc and Kensinger (2008) as reflecting differential recruitment for young and older adults during incidental encoding of emotional stimuli. Additionally, St. Jacques and colleagues (2009) recently highlighted age-related increases in ventromedial PFC activity as the primary change identified across a number of studies examining episodic emotional memory encoding in older adults. The current study replicates this *Fronto-amygdalar Age-related Differences in Emotion* (FADE) pattern in retrieval of autobiographical memory.

The majority of episodic memory studies exhibiting the FADE pattern have compared encoding of negative and neutral images. Consistent with these comparisons, visual examination of the percent signal change during negative and positive events suggests that the enhanced recruitment of the vmPFC in older adults is driven by activity during retrieval of negative events. Young adults, on the other hand recruit this region to a similar extent for neutral and negative events. Such findings suggest that older adults recruit this region during the reappraisal and evaluation of negative memories, whereas young adults do not.

Conclusions

The current study served as an important step in understanding the underlying cognitive and neural mechanisms of age-related changes to autobiographical memory retrieval. Specifically, Experiment 1 did not find a positivity effect for autobiographical memories elicited by music cue, but did identify the overgenerality effect. This age-related overgenerality effect primarily reflected older adults' impairment in the maintenance and implementation of task instructions. Experiment 2 demonstrated that young and older adults relied on the same neural network during retrieval of specific autobiographical memories, but not general memories. Additionally, the FADE pattern that has been reported in episodic encoding studies was replicated, with older adults over-recruiting the ventromedial PFC during emotional autobiographical memory retrieval. The results of these experiments provide an important and essential foundation for future studies examining the age-related changes to autobiographical memory retrieval, leading to a better understanding of why these changes occur.

Table 1. Neuropsychological information for young and older adults in Experiments 1 and 2.

	Experiment 1		Experiment 2	
	Young Adults	*Older Adults*	*Young Adults*	*Older Adults*
Depression Scale				
BDI	6.59(7.53)	4.12(2.87)	-	-
GDS	-	-	1.38(1.25)	.89(1.05)
Stroop	.20(.11)	.29(.19)	.18(.12)	.26(.15)
Working Memory Accuracy	.83(.26)	.78(.20)	.92(.05)	.94(.38)
Task Switching				
Local Cost	.60(.22)	.61(.38)	.54(.31)	.45(.37)
Global Cost	.18(.12)	.19(.15)	.41(.24)	.26(.66)

BDI= Beck's Depression Inventory; GDS= Geriatric Depression Scale
Group means are presented, standard deviations are presented in parentheses

Table 2. Regions in which activity was greater for specific autobiographical events relative to the control task.

Region of Interest	Hemisphere	BA	MNI Coordinates x	Y	z	t-value	K
Young and Older Adults							
Anterior Cingulate	R	32	10	22	38	7.63	2575
	R	24	12	2	46	5.74	
	L	32	-10	38	16	4.28	69
Superior Frontal Gyrus	L	9	-16	44	30	4.24	
	L	9	-18	46	20	3.42	
Postcentral Gyrus	R	2	52	-32	58	5.63	53
		2	42	-42	62	2.98	14
		3	28	-40	46	2.96	10
Inferior Parietal Lobule	R	40	34	-44	58	2.58	
Precuneus	R	31	18	-58	22	5.21	515
	L	19	-30	-80	38	3.68	108
Precuneus	L	7	-6	-68	54	3.53	49
Premotor Cortex	L	6	-24	-16	58	4.89	2198
Medial Prefrontal Cortex	R	10	30	44	26	3.64	150
	R	10	34	60	22	3.12	
Insula	R	13	36	26	16	4.46	78
	L	13	-34	14	20	4.12	122
Inferior Parietal Lobule	L	40	-48	-44	28	4.44	191
Superior Parietal Lobule	R	7	28	-58	44	4.26	10
Precentral Gyrus	R	6	60	2	36	4.23	44
	R	4	40	-20	40	3.56	109
	L	9	-32	4	40	3.26	18
Posterior Cingulate	R	30	22	-68	10	4.04	78
	L	31	-12	-32	44	4.02	31
	L	23	-8	-16	34	3.3	10
Inferior Frontal Gyrus	R	47	28	32	-8	4.01	104
		45	46	16	4	3.72	10
		45	48	14	22	2.97	24
	L	44	-58	6	18	3.32	20
Middle Temporal Gyrus	R	39	36	-68	30	3.9	37
Middle Occipital Gyrus	L	19	-54	-70	-8	3.7	20
Superior Temporal Gyrus	L	22	-58	-26	0	3.28	50
	R	21	62	-10	-2	3.12	22
Amygdala	R	na	24	-10	-14	2.89	11
Inferior Parietal Lobule	R	40	68	-38	26	2.78	17
Young Adults > Older Adults							
Fusiform Gyrus	R	37	44	-40	-18	3.69	38

Precentral Gyrus	L	6	-38	-4	46	3.41	17
			-62	-16	44	3.29	13
Anterior Cingulate	L	24	-14	-12	46	3.34	11
Medial Prefrontal Cortex	R	10	14	42	-6	3.09	21
Cuneus	L	18	-14	-82	22	3.06	24
Older Adults > Young Adults							
Insula	R	13	34	-24	24	3.67	29
Medial Prefrontal Cortex	L	10	-20	54	-2	3.6	32
Premotor Cortex	R	6	10	-18	60	3.49	14

Up to three local maxima reported for each cluster reported significant at uncorrected threshold of $p<.005$; $k \leq 10$ voxels.

BA= approximate Brodmann Area; L=left, R=right

Table 3. Regions in which activity was greater for general autobiographical events relative to the control task.

Region of Interest	Hemisphere	BA	MNI Coordinates x	Y	z	t-value	k
Young and Older Adults							
Precentral Gyrus	L	4	-36	-16	58	7.92	9110
Anterior Cingulate	R	32	14	18	46	7.82	
Posterior Cingulate	L	23	-8	-52	12	5.58	1279
			-8	-16	34	4.11	98
	R	23	10	-20	30	3.65	
		30	18	-68	10	2.56	20
Angular Gyrus	R	39	28	-60	30	5.29	80
Precuneus	R	7	24	-70	30	2.79	
Middle Temporal Gyrus	R	39	36	-68	24	2.4	
	L	39	-42	-76	22	2.69	23
Fusiform Gyrus	L	37	-44	-42	-22	5.13	144
Superior Parietal Lobule	L	7	-8	-68	56	4.91	139
			-30	-58	48	3.13	21
Inferior Parietal Lobule	R	40	50	-36	30	4.46	277
Postcentral Gyrus	R	2	48	-26	28	3.17	
	L	43	-50	-16	16	2.85	10
Inferior Temporal Gyrus	L	37	-44	-66	-8	4.28	249
Medial Prefrontal Cortex	R	9	22	38	22	4	80
Superior Temporal Gyrus	R	39	46	-54	10	3.72	54
	L	38	-36	18	-30	2.67	13
Superior Frontal	R	10	30	62	22	3.72	20
	R	9	30	34	36	3.28	139
Lingual Gyrus	R	19	34	-58	0	3.62	45
	L	18	-6	-82	-8	2.94	62
	R	18	2	-84	0	2.51	
Cuneus	L	17	-6	-96	2	2.74	43
	R	18	2	-96	12	2.55	
Insula	R	13	30	-14	26	2.71	12
Young Adults > Older Adults							
Fusiform Gyrus	R	37	44	-48	-14	4.98	370
Cuneus	R	18	26	-96	-6	3.96	460
	L	17	-22	-84	6	3.12	11
Middle Occipital Gyrus	R	19	34	-94	14	3.69	
	L	19	-22	-102	14	3.03	14
Inferior Frontal Gyrus	L	47	-34	36	4	3.95	116
	L	47	-46	48	-4	3.11	
Insula	R	13	32	-38	20	3.57	23

Parahippocampal Gyrus	R	19	18	-46	-10	3.47	74
Lingual Gyrus	L	18	-10	-74	-12	3.39	29
Superior Temporal Gyrus	R	22	62	-60	8	3.29	13
	R	22	52	-14	-12	3.13	10
	L	22	-54	-54	8	3.13	14
Precentral Gyrus	L	4	-54	-8	48	3.25	14
Superior Parietal Lobule	L	7	-14	-68	64	3.2	11
Postcentral Gyrus	R	1	68	-18	30	3.19	13
Middle Temporal Gyrus	L	22	-50	-42	-2	3.11	22
Older Adults > Young Adults							
Precuneus	L	7	-20	-56	36	4.31	160
Posterior Cingulate	L	31	-18	-52	24	3.94	
Supramarginal Gyrus	R	40	36	-52	32	4.06	37
Medial Prefrontal Cortex	L	10	-18	60	8	3.28	25

Up to three local maxima reported for each cluster reported significant at uncorrected threshold of $p<.005$; $k \leq 10$ voxels.

BA= approximate Brodmann Area; L=left, R=right

Table 4. Regions in which activity was greater for emotional relative to neutral autobiographical events.

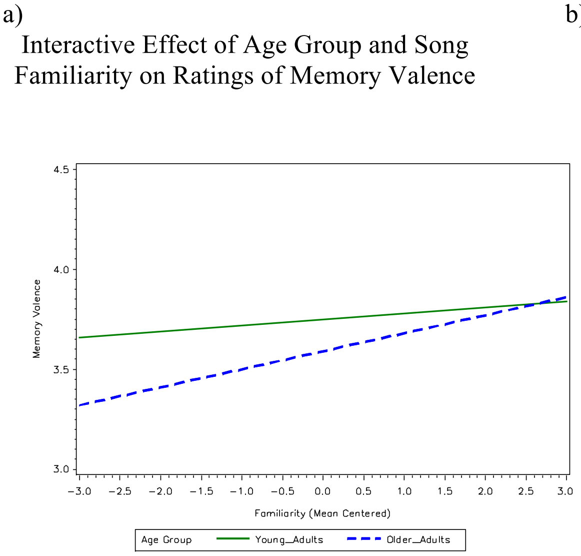
Region of Interest	Hemisphere	BA	MNI Coordinates x	y	z	t-value	k
Common activity for young and older adults							
Inferior Frontal Gyrus	R	47	28	22	-20	3.63	11
Young > Older adults							
Superior Temporal Gyrus	L	22	-66	-26	6	4.42	71
Superior Temporal Gyrus	R	41	60	-20	8	3.57	97
Middle Temporal Gyrus	R	22	64	-32	2	3.26	
Inferior Frontal Gyrus	L	47	-38	36	0	3.13	10
Older > Young adults							
Medial Prefrontal Cortex	R	11	4	28	-12	4.52	83
Superior Occipital Gyrus	L	19	-32	-92	20	3.68	326
Cuneus	L	18	-16	-80	12	3.43	
Middle Occipital Gyrus	R	37	38	-62	-2	3.54	22
Medial Frontal Gyrus	R	6	8	-32	66	3.41	23
Precuneus	L	7	-20	-60	54	3.24	47
Cuneus	R	18	10	-94	12	3.19	44
Middle Occipital Gyrus	R	18	16	-104	14	2.97	
Lingual Gyrus	L	17	-14	-94	-2	3.03	15
		18	-10	-80	-14	3	15

Up to three local maxima reported for each cluster reported significant at uncorrected threshold of $p<.005$; $k \leq 10$ voxels.

BA= approximate Brodmann Area; L=left, R=right

Figure 1. Effects of (a) song familiarity ratings and (b) song valence ratings on ratings of memory valence, as a product of age group.

a)



b)

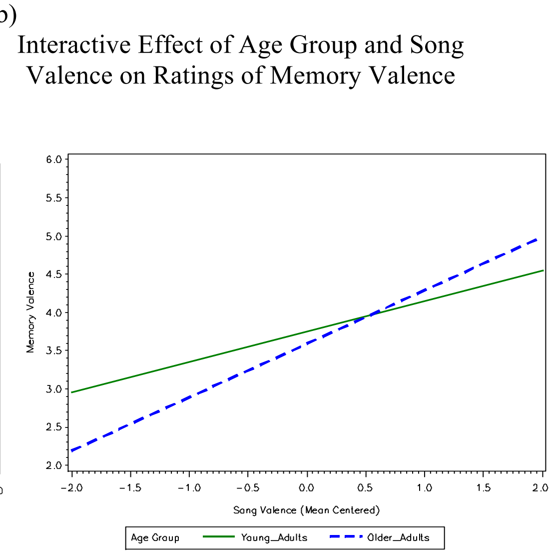


Figure 2. Effect of song valence ratings on memory specificity, as a product of age group.

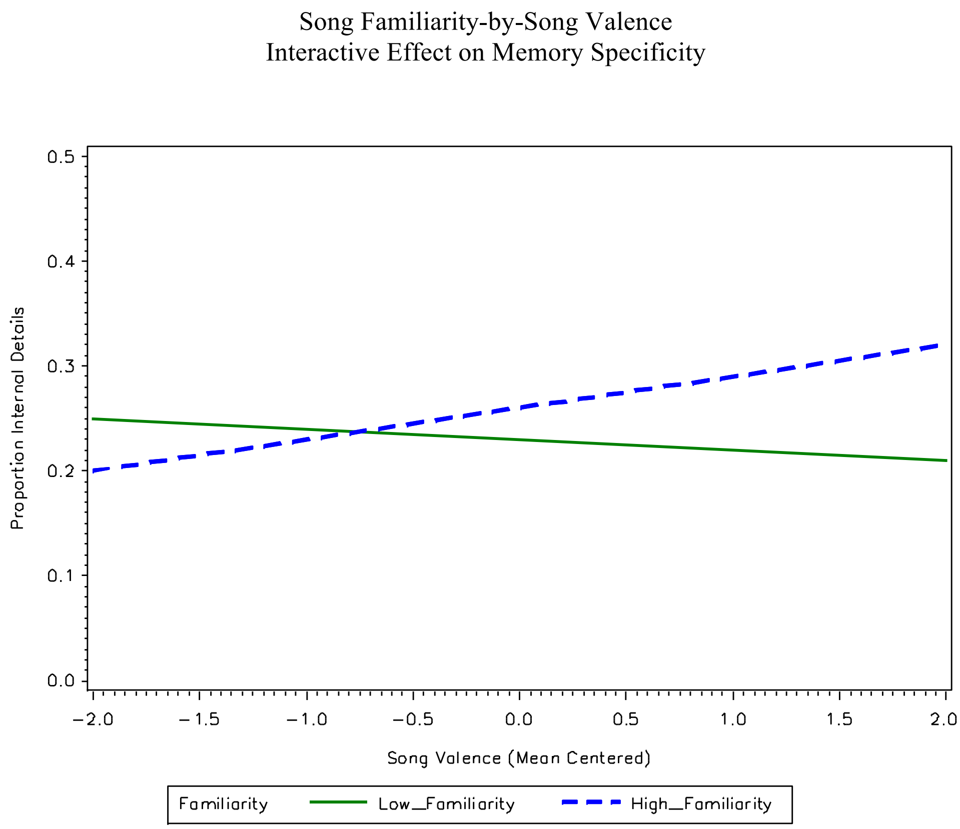
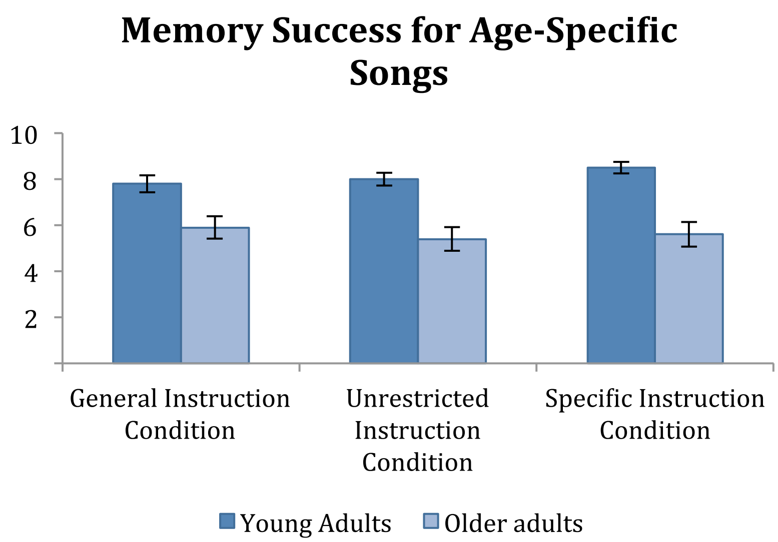


Figure 3. Event memory success for age-specific songs as a produce of age group and instruction condition. Memory success is presented as (a) number of memories retrieved and (b) number of event memories retrieved.

a)



b)

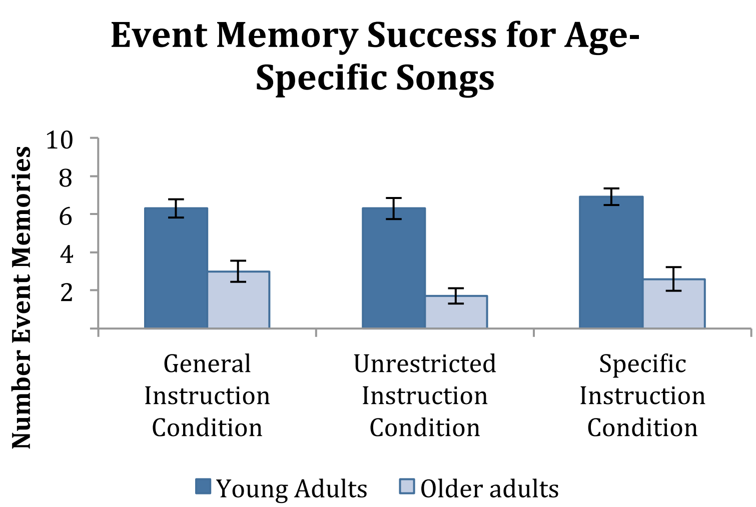
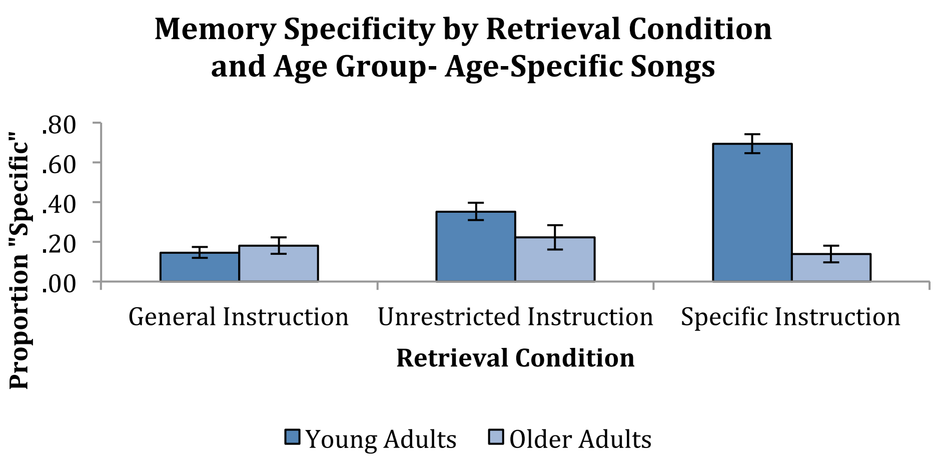


Figure 4. Memory specificity (as measured by specificity ratings) as a product of age group and instruction condition for (a) age-specific songs and (b) movie songs. Specificity is presented as the proportion of specific memories retrieved out of the number of event memories.

a)



b)

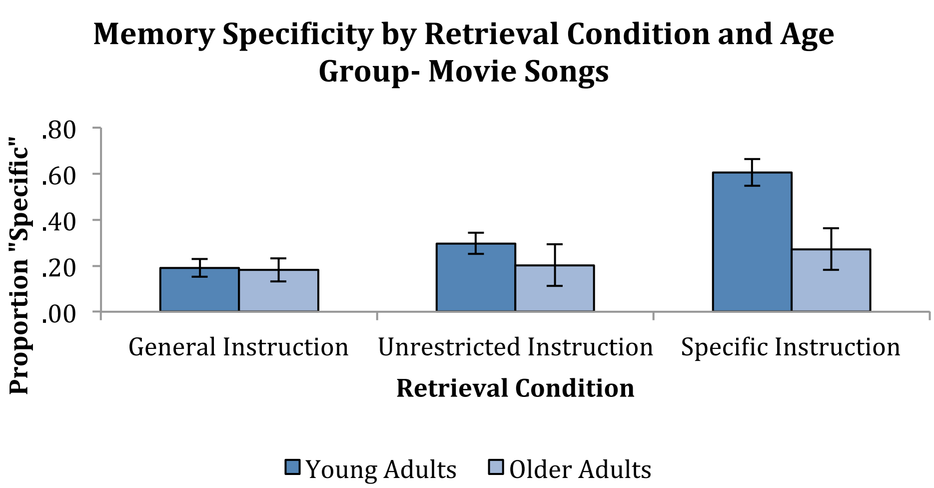
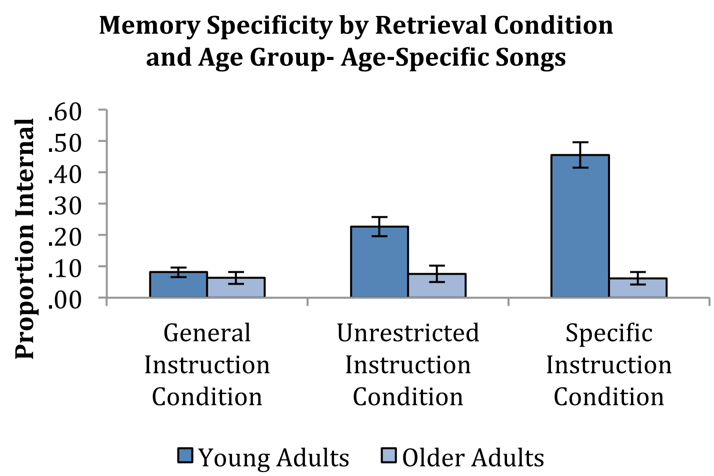


Figure 5. Memory specificity (as measured using the Autobiographical Interview scoring system) as a product of age group and instruction condition for (a) age-specific songs and (b) movie songs. Specificity is presented as the proportion of specific details retrieved out of the total number of details.

a)



b)

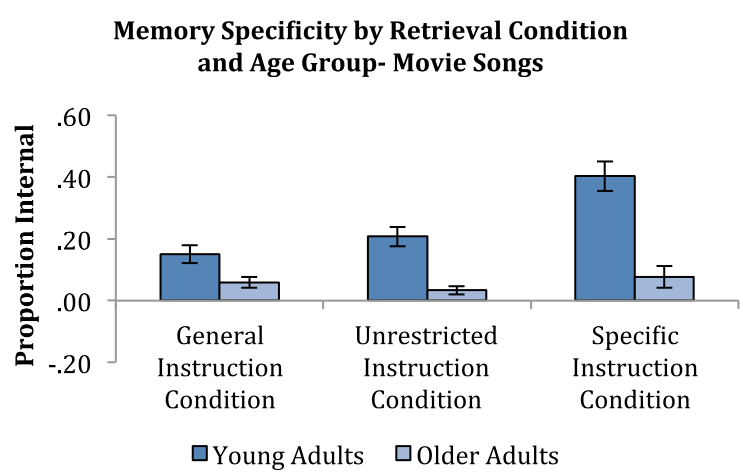


Figure 6. Memory details by subtype and age group, as measured using the Autobiographical Interview scoring system.

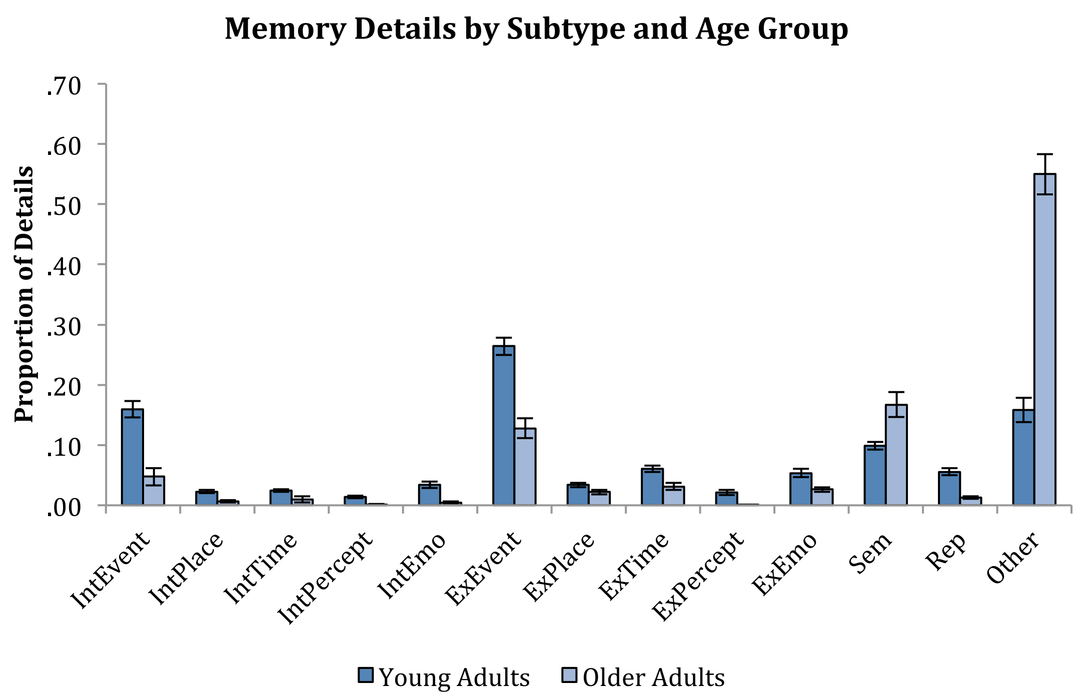


Figure 7. Neural activity associated with retrieval of specific autobiographical memories greater than control trials for young adults to a greater extent than older adults (purple), older adults to a greater extent than young adults (teal), and both young and older adults (yellow).

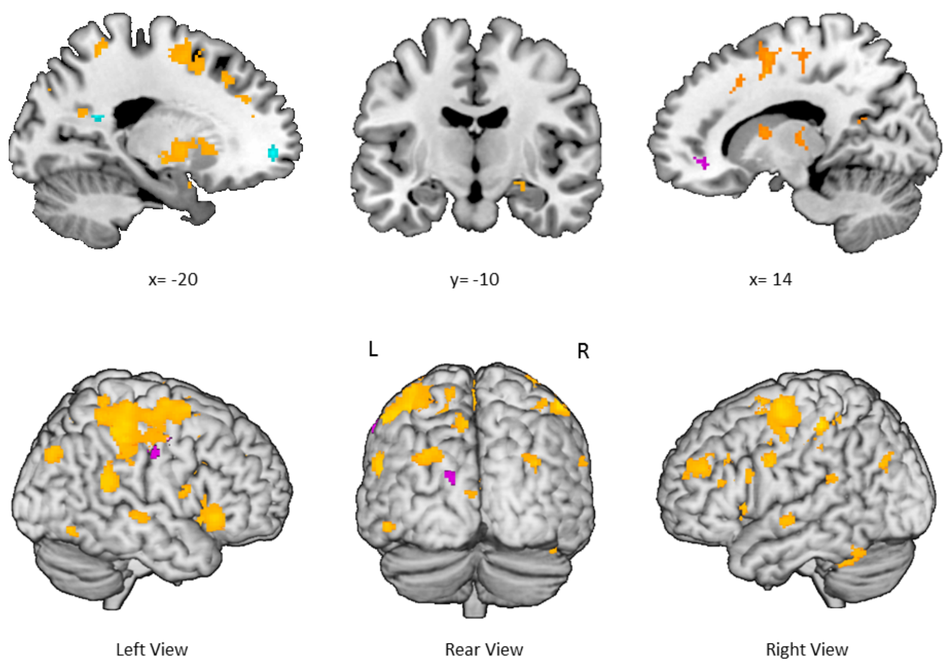


Figure 8. Neural activity associated with retrieval of general autobiographical memories greater than control trials for young adults to a greater extent than older adults (purple), older adults to a greater extent than young adults (teal), and both young and older adults (yellow).

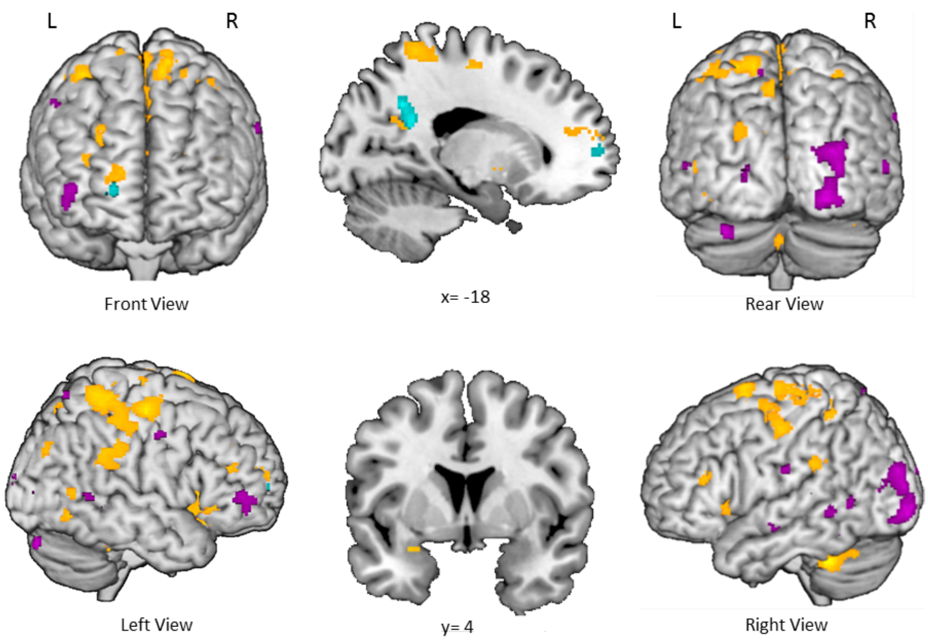


Figure 9. Neural activity associated with retrieval of emotional autobiographical memories greater than neutral events for young adults to a greater extent than older adults (purple), older adults to a greater extent than young adults (teal), and both young and older adults (yellow).

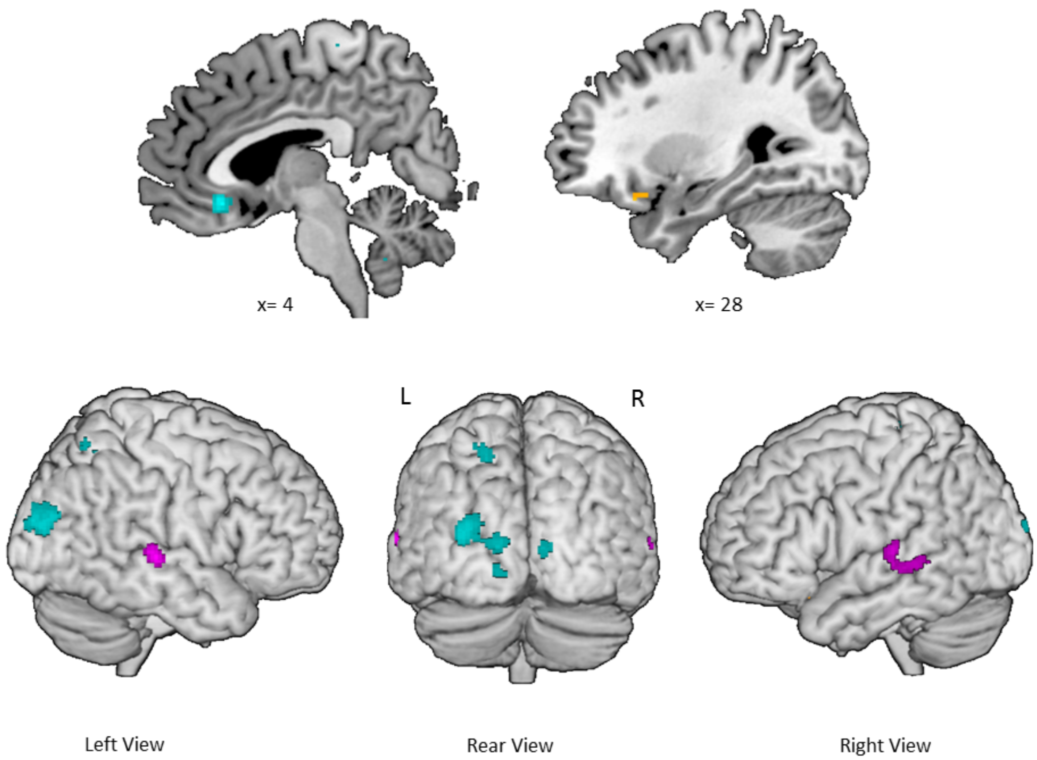
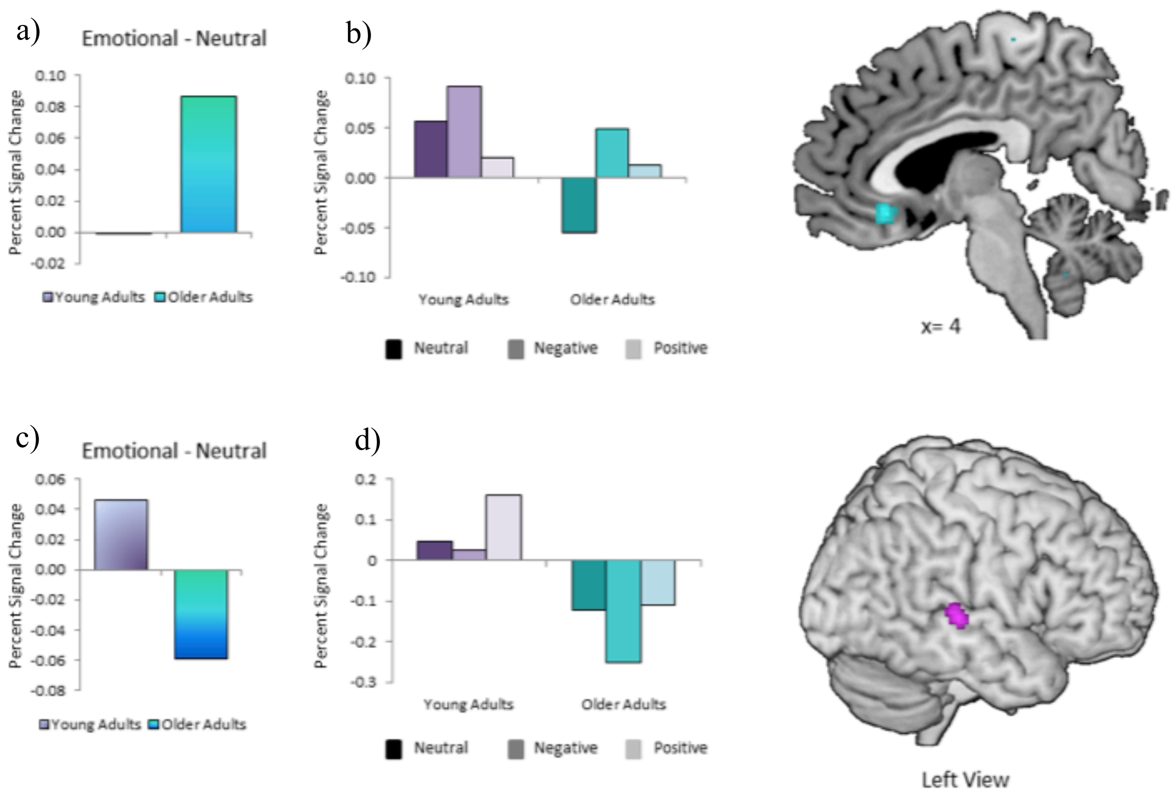


Figure 10. Percent signal change associated with a) emotional autobiographical events minus autobiographical neutral events in the ventromedial prefrontal cortex, b) positive, negative, and neutral autobiographical events in ventromedial prefrontal cortex, c) emotional autobiographical events minus autobiographical neutral events in the lateral temporal lobe, and d) positive, negative, and neutral autobiographical events in the lateral temporal lobe. Percent signal change associated with young adults is presented in purple, and percent signal change associated with older adults is presented in teal.



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