AGING AND IMPLICIT MEMORY FOR EMOTIONAL WORDS

by

Cristina Saverino

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Cristina Saverino

Masters of Arts

Department of Psychology, University of Toronto

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Abstract

The present study investigated age differences in implicit memory for positive, negative and neutral words. We also explored how cognitive control and time of testing influence emotional memory. Participants completed a one-back picture comparison task with superimposed distracting emotional and neutral words. Memory for distracting words was tested using an implicit memory test and cognitive control by a flanker task. Priming was significant for negative but not for positive and neutral words. Memory for distracting negative words was greater at non-optimal times of day for young adults but similar across the day for older adults. A high level of cognitive control was related to greater priming for negative words in young adults and lower priming in older adults. Priming for neutral words was enhanced in high cognitive control participants when stimuli contained emotional words that were relevant to one’s goals, implicating the use of emotion regulation at an unconscious level.
Acknowledgments

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# Table of Contents

Introduction..........................................................................................................................1

Methods..................................................................................................................................10
  Participants and Design........................................................................................................11
  Materials...............................................................................................................................11
  Experimental Procedure.......................................................................................................13
  Analyses.................................................................................................................................15

Results...................................................................................................................................16
  Participants............................................................................................................................16
  One-Back Picture Comparison Task.......................................................................................17
  Flanker Task..........................................................................................................................17
  Implicit Priming.....................................................................................................................18
    Priming for Negative and Neutral Words...........................................................................19
    Priming for Positive and Neutral Words...........................................................................21

Discussion...............................................................................................................................23
  Conclusion...............................................................................................................................29

References...............................................................................................................................30
List of Tables

Table 1: Demographic measures for participants in negative and positive groups .......... 16

Table 2: Task performance for young and older adults .................................................. 17

Table 3: Baseline completion rates for positive, negative and neutral words across age
groups .................................................................................................................................. 18

Table 4: Priming rate for neutral and negative words in morning and afternoon test
sessions across age groups ............................................................................................... 19

Table 5: Priming rate for neutral and positive words in morning and afternoon test
session across age groups ............................................................................................... 22
List of Figures

Figure 1: Mean rate of negative and neutral priming across age groups. Error bars represent standard error of the mean..........................19

Figure 2: Mean negative and neutral priming rates for young and older adults across high and low cognitive control groups. Error bars represent standard error of the mean........21

Figure 3: Mean rate of positive and neutral priming across age groups. Error bars represent standard error of the mean.................................................................21

Figure 4: Mean positive and neutral priming rates for young and older adults across high and low cognitive control groups. Error bars represent standard error of the mean..........22
Aging and Implicit Memory for Emotional Words

Aging is often associated with declines in cognitive function and overall health. Older adults tend to exhibit poorer episodic memory, reduced working memory capacity, slower processing speed and diminished attentional resources compared to younger adults (Zacks, Hasher, & Li, 1999; Verhaeghen & Salthouse, 1997; Belleville, Peretz, & Malenfant, 1996; Park et al., 1996; Salthouse, Babcock, & Shaw, 1991; Dobbs & Rule, 1989). Not all processes, however, decline with age. A common finding is that older adults’ performance on implicit memory tests remains stable or shows relatively small declines across the life span (Rowe, Valderrama, Hasher, & Lenartowicz, 2006; Light, Prull, La Voie, & Healy, 2000; Jelicic, Craik, & Moscovitch, 1996; La Voie & Light, 1994; Light & Singh, 1987). Furthermore, explicit memory can be enhanced and age differences reduced when stimuli are emotionally salient. This effect has been observed when comparing emotional facial expressions (Grady, Hongwanishkul, Keightley, Lee, & Hasher, 2007; Knight et al., 2007), pictures of scenes (Tomaszczyk, Fernandes, & Macleod, 2008; Knight et al., 2007; Comblain, D’Argembeau, Van der Linden, & Aldenhoff, 2004; Charles, Mather, & Carstensen, 2003), words (Kapucu, Rotello, Ready & Seidl, 2008; Kensinger & Schacter, 2008; Thomas & Hasher, 2006), and stories (Carstensen & Charles, 1994; Yoder & Elias, 1987) to neutral equivalents.

Although there is a benefit for affective items, a discrepancy exists between the recall of positive and negative information in young and older adults. Young adults are widely reported to have enhanced memory for negative compared to positive and neutral information, whereas older adults often exhibit better memory for positive compared to negative and neutral information (Kensinger, 2008; Mikels, Larkin, Reuter-Lorenz,
Carstensen, 2005; Thomas & Hasher, 2006; Mather & Knight, 2005; Leigland, Schulz, & Janowsky, 2004; Kennedy, Mather, & Carstensen, 2004; Charles et al., 2003, Experiment 1; Mather & Carstensen, 2003, Experiment 1). The memory enhancement for positive items seen in older adults is known as the positivity effect.

The positivity effect can be found across different forms of explicit memory and with varying types of information. For instance, in a simple recall task elderly and middle age participants, as opposed to younger participants, significantly recalled more positive than negative or neutral pictures (Charles et al., 2003). Thomas and Hasher (2006) observed similar findings for affective words. The task required participants to make a parity decision regarding two numbers, with distracting emotional or neutral words appearing between the critical numbers. On a subsequent recognition test, positive distracting words were recognized best by older adults, while the opposite pattern was observed by younger adults. Autobiographical and working memory studies also report evidence in support of a positivity effect. In a longitudinal study, the autobiographical memories of a group of elderly women showed that past memories were recollected in a more positive manner than originally reported (Kennedy et al., 2004). Yet, younger colleagues only showed positively biased memories of past events when instructed to focus on their emotional states. In a working memory task, which required participants to hold either emotional or visual content in mind, younger adults had superior maintenance of affective information when the content was negative and older adults when the content was positive (Mikels et al., 2005).

One possible mechanism underlying the positivity effect is the role of attention or cognitive control. According to the socioemotional selective theory (SST), a switch takes
place over the life span from future-oriented goals to present-oriented goals, as older adults become aware that their time in life is limited (Carstensen, Fung, & Charles, 2003; Carstensen, Isaacowitz, & Charles, 1999). It is believed that this switch causes older adults to use more cognitive resources in trying to attain emotionally meaningful goals. Alternatively, younger adults who perceive time as expansive would attend more to the future; hence, focusing on acquiring knowledge and seeking out novelty. As the theory developed, older adults’ attainment of emotionally meaningful goals was thought to result in an increase or favouritism for positive over negative and neutral information (Carstensen & Mikels, 2005).

Support for this theory can be found in studies documenting better emotion regulation skills in older adults (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Gross et al., 1997). Older adults are also less likely to experience negative affect in their everyday lives (Kunzmann, Little, & Smith, 2000) and report more stable moods (Lawton, Kleban, Rajagopal, & Dean, 1992) compared to younger adults. In terms of physiology, older adults demonstrate significantly reduced autonomic responses to emotions (Levensen, Carstensen, Friesen, & Ekman, 1991). These findings showcase the use of cognitive control by older adults to reduce negative affect and increase positive affect.

Additionally, older adults have been shown to have an attentional bias for positive stimuli. When examining eye fixations in a dot-probe task, older adults exhibited an attentional bias away from negative faces and towards neutral (Mather & Carstensen, 2003) or positive (Isaacowitz, Wadlinger, Goren, & Wilson, 2006) faces; whereas, younger adults did not exhibit such a bias. A similar investigation in which positive and
negative pictures were paired with neutral pictures revealed that older participants, under full attention conditions, made a greater number of fixations towards positive images. When attention was divided using a tone task, a greater number of fixations were made towards the negative image (Knight et al., 2007). The change in fixations translated into recognition, with higher recognition for positive images during full attention (FA) and greater recognition of negative images under divided attention (DA) (Knight et al., 2007; Mather & Knight, 2005). Similarly, older adults who scored higher on tasks of cognitive control were more likely to recall positive pictures than those who scored lower on cognitive control (Mather & Knight, 2005). When comparing age-difference in recall for positive pictures after a 20 min versus 2-day delay, older adults recalled more positive pictures than younger adults across both test sessions. Age differences, however, were larger after the 48 hour delay than the 20 min delay, suggesting that older adults spend more time regulating memory towards positive affect after stimulus exposure than younger individuals (Mather & Knight, 2005). These results provide support for the premise that cognitive control over attention allows older adults to focus on goal-consistent or positive information.

The cortical pathways recruited during emotional tasks also exhibit age-related differences in emotional processing. The amygdala, an important area for emotional processing, exhibits greater activity in older adults in response to positive than to negative pictures (Mather et al., 2004). Younger adults demonstrate the opposite effect, with greater activity in response to negative pictures (Mather et al., 2004; Gunning-Dixon et al., 2003; Hamann, Ely, Hoffman, & Kilts, 2002; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). When processing emotional stimuli, functional magnetic resonance (fMRI)
studies have identified that young adults recruit more temporal-limbic areas, while older adults recruit prefrontal and parietal areas (St. Jaques, Dolcos, & Cabeza, 2009; Gunning-Dixon et al., 2003; Kensinger & Schacter, 2008). Considering that the prefrontal lobes are important for working memory and cognitive control (Kane & Engle, 2002; Miller & Cohen, 2001), it has been hypothesized that older adults’ engagement of the frontal lobes is to carry out goal-driven and controlled attentional processes (Hahn, Carlson, Singer, & Gronlund, 2006). Young adults, on the other hand, may use more automatic processes, guided by the limbic system. The amygdala, in particular, is associated with automatic processing of threatening or emotional stimuli. Often times the amygdala is active during the subliminal presentation of emotional items that occur without conscious awareness (Hatfield, Cacioppo, & Rapson, 1992; Zald, 2003). Emotional intensity and experienced arousal have been closely linked to the amygdala (Gläscher & Adolphs, 2003). The evaluation of valence, however, involves prefrontal cortex (PFC) (Dolcos, LaBar, & Cabeza, 2004; Kensinger & Corkin, 2004; Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003). This suggests that there are two subsystems active during emotional processing: (1) an automatic, limbic-based system that detects arousal and (2) a controlled, goal-oriented, prefrontal system that categorizes valence.

Despite the large amount of evidence, both behavioural and neural, for the positivity effect, it is nevertheless the case that this effect is variable and has failed to be consistently shown across studies. For example, findings from studies with encoding under intentional memory instructions (forewarned of subsequent memory test), rather than incidental instructions in which participants are unaware of an upcoming memory test, fail to show a positivity effect (Kensinger, Brierly, Bedford, Growdon, & Corkin,
Furthermore, studies that require emotional ratings of stimuli during encoding are less likely to document increased memory for positive information in older adults than studies that do not (Kensinger et al., 2002; Comblain et al., 2004; Grady et al., 2007). Compared to recall procedures in memory tests, recognition methods can significantly reduce or even eliminate enhanced memory for positive items (Murphy & Issacowitz, 2008; Charles et al., 2003, Experiment 2; Mather & Carstensen, 2003, Experiment 2; Grady et al., 2007). Other differences in methodology that may influence emotional memory include the type of stimuli (verbal vs. pictorial), frequency of their presentation (once vs. twice), and delay between stimulus presentation and test (15 min, 30 min, 2 day etc).

Contrary to the research supporting the positivity effect, some studies have shown that older adults exhibit increased memory for negative information (Grady et al., 2007; Gruhn, Smith, & Baltes, 2005; Denburg, Buchanan, Tranel, & Adolphs, 2003), or no difference in memory for positive and negative information (Murphy & Isaacowitz, 2008; Comblain et al., 2004; Charles et al., 2003, Experiment 2; Kensinger et al. 2002). Grady and colleagues (2007) demonstrated that recognition of negative faces was superior to either positive or neutral faces, irrespective of age. They also showed that age differences in memory were greatest for negative faces, while recognition of positive and neutral faces did not differ, suggesting that older adults may be more vulnerable to age related changes in response to negatively valenced items. Additionally, a meta-analysis conducted by Murphy and Isaacowitz (2008) of emotional memory studies found that positive and negative information were equally salient for young and older adults. Older adults, however, had a smaller negativity preference particularly for recognition memory.
Based on these findings, an alternative view to the SST may argue that negative information among elderly is ineffectively processed and consequently causes memory for negative items to be reduced in reference to positive. This view would counter the arguments made by the SST that the positivity effect is the result of older adults’ effort to attain emotional goals, perhaps it is the deficiency in processing negative items that may give rise to the positivity effect.

Despite the failure to replicate a positivity effect across studies in older adults, findings in emotional memory have established that affective information is remembered better than non-affective information (Hamann, 2001 for review). Superior memory for emotional material has been termed the emotionally enhanced memory (EEM) effect (see Talmi, Schimmack, Paterson, & Moscovitch, 2007).

Although much attention has been placed on emotion and explicit memory, little is known regarding the influence of emotion on implicit tests of memory in older adults. One of the most basic forms of implicit memory is repetition priming or perceptual priming. Repetition priming is defined as recent exposure to an item during study that results in the ability to identify or produce a similar item at test with greater accuracy and/or speed (Nyberg & Tulving, 1996; Schacter & Tulving, 1994). This form of implicit memory is often associated with reduced activation in posterior perceptual regions and prefrontal cortex (Schacter, Wig, & Stevens, 2007; Schacter & Badgaiyan, 2001). The decrease in activity likely reflects greater processing efficiency in individuals, as recent exposure with the material allows for perceptual representations to be at a heightened level of accessibility. Some researchers argue that perceptual priming does not occur in a
consciously controlled manner and is driven by bottom-up automatic processes (Craik, Moscovitch, & McDowd, 1994; Schacter & Buckner, 1998).

Studies have shown that implicit memory is relatively spared with age (Tulving & Schacter, 1990; Richardson-Klavehn & Bjork, 1988). Common repetition tasks that assess priming include: word fragment completion, word stem completion, lexical decision, rereading, and perceptual identification under degraded conditions. Although most studies have shown comparable priming effects across age groups (Wiggs, Weisberg, & Martin, 2006; Jelicic, et al., 1996; Light, La Voie, & Kennison, 1995), Rowe and colleagues (2006) observed enhanced priming among older adults. The study required participants to complete word fragments based on distracting words presented during a one-back picture comparison task. Results showed that older individuals were most susceptible to distraction and had greater priming rates than younger adults. This implies that the failure to inhibit during an implicit memory task results in increased allocation of attention to irrelevant information.

Only one study to our knowledge examined age differences in implicit memory for emotional information (LaBar et al., 2005). The study found that perceptual priming of negative and neutral scenes was preserved in Alzheimer patients and healthy older controls. Priming effects were strongest, as indicated by shorter exposure duration, for negative scenes. Additional research, however, needs to be conducted to examine age differences in implicit memory for positive and negative information. In terms of the influence of emotion regulation on priming, a study with young adults showed that emotion regulation strategies increased recall of emotional pictures but had no effect on implicit memory (Dillon, Ritchey, Johnson, & LaBar, 2007). The results demonstrate that
emotion regulation strategies affect explicit but not implicit memory. Implicit memory occurs at an unconscious level and is believed to act without the use of regulation strategies. The SST, however, proposes that emotion regulation strategies are chronically available for older adults whereas they are only exhibited in certain contexts for younger individuals (Mather & Knight, 2005). Nonetheless, no studies to this date have examined implicit memory for emotional information and the use of cognitive control processes.

Furthermore, performance on implicit memory tasks is influenced by age related changes in circadian arousal. Attentional control is best at peak versus off peak times of day and therefore, the time of day that individuals are tested influences explicit, as well as implicit test performance (Yoon, May, Goldstein, & Hasher, in press). Peak time of day is commonly early morning for older adults and later in the afternoon for younger adults. May (1999) found that problem solving in the face of distraction was executed best in the morning for those who reported being morning type individuals, and in the evening for those who reported being evening type individuals. In regards to implicit memory for non automatic processes, research has shown that participants perform best when tested at their off-peak time of day (Yang, Hasher, & Wilson, 2007; Rowe et al., 2006; May & Hasher, 1998; May, Hasher, & Stoltzfus, 1993).

The overall objective of the current study was to examine age differences in implicit memory for emotional words using a word fragment completion task. The task was a modification of Rowe, Valderrama, Hasher and Lenartowicz’s (2006) experimental procedure. Emotional (positive or negative) and neutral words were presented superimposed over pictures during a one-back picture comparison task. Participants were instructed to ignore the words during the one back task. Implicit memory or priming for
these words was assessed by the proportion of word fragments correctly completed. Priming rates were explored in reference to level of cognitive control and time of testing. To identify how different levels of cognitive control influence emotional priming, we administered a common cognitive control measure known as the arrow flanker task (Eriksen & Eriksen, 1974). For differences in circadian arousal patterns, participants were randomly assigned to either morning or afternoon testing sessions.

It was hypothesized that implicit memory does not involve emotion regulation and thus priming for positive, negative and neutral words should not differ across age groups. Although we predicted no age group effect, an effect of valence type was expected. Implicit memory was hypothesized to be greater for negative words than positive or neutral words. In terms of time of testing, implicit memory would be expected to be greater at participants’ off peak versus peak time of day. The influence of cognitive control, however, can only be speculated. Mather and Knight (2005) argue that emotion regulation goals are chronically accessible for older adults, even at an unconscious level, but that the positivity effect only arises when cognitive control processes can be recruited to regulate emotional goals. Implicit memory, however, allows for limited opportunity to use cognitive control processes. Nevertheless, older adults with a high level of cognitive control might be able to activate unconscious emotion regulation goals to a greater degree than those with low cognitive control, and thus should display increased priming for positive words. The affect that cognitive control has on young adults is less understood, as emotional goals are believed to only be active in certain contexts (Mather & Knight, 2005).

Methods
Participants and Design

Younger adults, between 18-28 years old (n = 39, 26 females and 13 males), and older adults, between 60-80 years old (n = 38, 20 females and 18 males), participated in the study. Participants were recruited from the University of Toronto or from the participant pool at the Rotman Research Institute at Baycrest. Older adults received monetary compensation, and younger adults received either course credit or monetary compensation. All participants had learned English prior to the age of 6 years old. No history of psychological or neurological illness was reported based on a pre-screening interview.

The design was a 2 (age: young and old) X 2 (test of time: morning and afternoon) X 2 (level of cognitive control: high and low) X 2 (emotion: emotional and neutral) mixed factorial: with age, time of testing and level of cognitive control as between-subjects factors, and emotion as a within subjects factor. Two separate emotional conditions were manipulated between subjects, one group received positive and neutral words, and the other group received negative and neutral words. The main dependent measure was priming for emotional and neutral words from the word fragment completion task.

Materials

Sixty-six line drawings were selected from Snodgrass and Vanderwart (1980) and coloured red. Six of the drawings were used on practice trials and the remaining drawings appeared during the one back picture comparison task. Superimposed on the line drawings were either random letter strings (20 in total) or words (40 in total: 20 target and 20 filler). Half the words were emotional (positive or negative) and half neutral.
Three lists of 10 positive, negative and neutral word types were created. One list from each word type was assigned as the target word list and the other as the filler word list. The lists were counterbalanced, so that each list appeared equally as often as the target and filler list. Bradley and Lang’s (1999) set of Affective Norms for English Words (ANEW) were used to equate the emotional lists on valence and arousal ratings. Neutral, positive and negative lists were matched based on previously established word fragment completion norms for young (M = .25, SD = 0.19) and older (M = .26, SD = .21) adults (Ikier, 2005). Arousal was rated higher for emotional lists (negative M = 5.88, SD = 1.00; positive M = 5.98, SD = .85) than for neutral lists (M = 4.06, SD = .49).

Participants completed a version of the flanker task as a measure of cognitive control. The target stimulus was always in the centre of the screen. It was presented either above or below a fixation cross. The fixation cross was shown prior to each experimental trial. A trial consisted of a central arrow pointing to the left (<) or right (>). There were three possible trials in which the target arrow was (1) presented alone, (2) flanked with other arrows or (3) flanked with x’s. The stimuli flanking the target arrow were either congruent (flanking arrows pointed in the same direction, e.g., > > > > > > >), incongruent (flanking arrows pointed in the opposite direction, e.g., < < < > < < <) or neutral (e.g., x x x > x x x).

Implicit memory for distracting words was tested using a word fragment completion task. Participants were required to complete a total of 60 word fragments. Twenty of the fragments could be completed from target words shown during the one-back task (10 emotional and 10 neutral). Twenty were control fragments or items from the list not seen by participants (10 emotional and 10 neutral). These control fragments
were taken from the last remaining counterbalance list (3 lists in total: one assigned as
target list for the one-back and fragment task, second assigned as filler list for the one-
back task). The final 20 were easily solved fragments that were used to increase
participants’ confidence, and reduce the awareness between the one-back task and word
fragment completion task. Old (target), new (control) and easy word fragments were
psuedo randomly distributed throughout the list.

The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh,
1975) was used to assess mental status of participants. The Mill Hill Vocabulary Scale
(Raven, 1982) was administered as a measure of intellectual function. It is more specific
to verbal intelligence, and is based on the participants’ ability to explain the meaning of a
list of words. To differentiate between morning and evening type persons, the MEQ by
Horne and Östberg (1976) was administered. High scores identify morning type
individuals and low scores classify evening type individuals. Data on personality, mood
and emotional sensitivity were also collected but will not be reported in the current study.
The MMSE, Mill Hill Vocabulary Scale, MEQ, personality, mood and emotional
sensitivity assessments were administered at the end of the test session.

*Experimental Procedure*

The experiment involved a one-back picture comparison task, followed by the
flanker task, and then a word fragment completion task. After the word fragment
completion task, participants received a series of questionnaires. Participants were
counterbalanced and randomly assigned to a morning (prior to 12:00 pm) or afternoon
(after 12:00 pm) testing session.
Testing took place on a lab computer using E-Prime 1.0 Software (Schneider, Eschman, & Zuccolotto, 2002). During the one-back picture comparison task a rapid stream of 60 individual line drawings were presented to participants, 20 were superimposed with random letter strings, 20 with target words (10 emotional and 10 neutral), and 20 with filler words (10 emotional and 10 neutral). Instructions were given to ignore the random letter strings or words and to press the spacebar when two consecutive pictures were identical. Six practice trails were given before the task began. The pictures superimposed with letter strings or words were displayed for 1000 ms, followed by an interstimulus interval (ISI) of 500 ms. The presentation sequence was as follows: 5 pictures superimposed with random letter strings (primacy buffer), 50 pictures with either random letter strings (n = 10) or words (n = 40) superimposed, and 5 pictures with random letter strings superimposed (recency buffer). Target words were psuedorandomly intermixed throughout the task. For every block of 10 words there were 4 targets, 4 fillers and 2 random letter strings. Non-target words appeared over consecutive pictures. A total of 10 picture repeats occurred throughout the one-back task.

Following the one-back picture comparison task, participants completed the flanker task. At the onset of the flanker task, participants gained practice responding to left and right arrow keys (40 trials). Once familiar with the left and right arrow keys, participants were given 28 practice trials in which they were instructed to respond only to the arrow in the centre of the string onscreen. The string consisted of congruent, incongruent, or neutral flankers. Participants then performed 72 experimental trials that included 18 of each condition (congruent, incongruent, neutral, or single). The trials were presented in a fixed random order, with no more than three consecutive iterations of the
same type of response or trial. The arrow remained on the screen until the participant made a response by pressing a key corresponding to either “<” or “>”, followed by a blank screen with a black fixation cross for 1000 ms. The flanker task took approximately 5-6 min to complete. To ensure that the time lapse between the one back task and word fragment completion task was a total of 10 min, participants completed a SUDOKO puzzle to make up for the remaining time.

The word fragment completion task involved 60 word fragments. The fragments were presented in pseudo-random order. Each word fragment appeared on the screen for 3000 ms (500 ms ISI). Instructions were given for participants to respond aloud with the first word that came to mind. Verbal responses were recorded and coded at a later time. Participants were questioned after completing the word fragment task as to whether they noticed a connection between any of the tasks. Those that noticed a connection between study and test were excluded and replaced with unaware participants.

Analyses

To examine demographic and task performance differences across age (young, old) and valence conditions (positive, negative) we ran a series of analyses of variance (ANOVA). Independent analyses were run for demographic, one-back task performance and flanker performance, with age and valence as between subject factors. Priming based on the word fragment completion task was analyzed separately for positive and negative valence. We ran a repeated measures ANOVA, with emotion (emotion, neutral) as a within-subject factor, and age (young, old) and time of testing (morning, evening) as between subjects factors, unless otherwise specified. An alpha level of .05 was used for all statistical tests.
Results

Participants

Three younger adults and 4 older adults reported being aware of a connection between the study phase and word fragment completion task, and were replaced with unaware participants. One young adult and 3 older adults performed below 70% accuracy (hits minus false alarms) on the one-back task and were excluded from analyses. Young adults had a mean age of 21.94 years ($SD = 2.59$), and 15.31 years ($SD = 1.41$) of education. Older adults had a mean age of 68.13 years ($SD = 5.85$) and 15.55 years ($SD = 2.53$) of education (see Table 1).

Table 1: Demographic measures for participants in negative and positive groups

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th></th>
<th>Positive</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M</td>
<td>SD</td>
<td>N</td>
</tr>
<tr>
<td>Young Adults</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>17</td>
<td>21.76</td>
<td>2.70</td>
<td>18</td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>17</td>
<td>15.12</td>
<td>1.58</td>
<td>18</td>
</tr>
<tr>
<td>MMSE</td>
<td>17</td>
<td>29.59</td>
<td>0.71</td>
<td>18</td>
</tr>
<tr>
<td>Mill Hill Vocab</td>
<td>17</td>
<td>17.65</td>
<td>4.21</td>
<td>18</td>
</tr>
<tr>
<td>MEQ</td>
<td>17</td>
<td>44.53</td>
<td>6.82</td>
<td>18</td>
</tr>
<tr>
<td>Older Adults</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>16</td>
<td>68.88</td>
<td>6.08</td>
<td>15</td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>16</td>
<td>15.13</td>
<td>2.66</td>
<td>15</td>
</tr>
<tr>
<td>MMSE</td>
<td>16</td>
<td>28.94</td>
<td>1.39</td>
<td>15</td>
</tr>
<tr>
<td>Mill Hill Vocab</td>
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<td>4.58</td>
<td>15</td>
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<tr>
<td>MEQ</td>
<td>16</td>
<td>56.94</td>
<td>8.24</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: MMSE = Mini Mental State Exam, and MEQ = Morningness/Eveningness Questionnaire

Young adults ($M = 29.69$, $SD = .58$) performed better on the MMSE than older adults ($M = 28.97$, $SD = 1.22$), $F(1,62) = 9.25$, $p = .003$, although all older adults scored in the normal range of this test (i.e., >26). Older adults ($M = 23.65$, $SD = 4.18$), however, scored significantly higher on the Mill Hill Vocabulary Scale (young adults, $M= 18.43$, $SD = 3.70$), $F(1,62) = 29.58$, $p < .001$. Scores on the MEQ were also greater for older adults (young adults, $M = 44.21$, $SD = 8.33$; older adults, $M = 57.45$, $SD = 7.80$),
signifying more morning type individuals in the older age group (F(1,62) = 42.83, p < .001). There were more neutral than evening type people for young adults (evening = 13, neutral = 21), and a similar number of morning and neutral type people for older adults (morning = 14, neutral = 15). There was no significant effect of assignment of participants into positive and negative conditions on years of education, MMSE, Mill Hill Vocabulary or MEQ within each age group.

One Back Picture Comparison Task

Performance on the one-back picture task was assessed by overall accuracy (hits minus false alarms) and reaction time (RT) on correct trials. Older adults (M = 8.97, SD = .95) were significantly less accurate than younger adults (M = 9.74, SD = .74), F(1,62) = 13.58, p < .001; yet, reaction time (RT) for correct trials did not differ across age groups (Table 2). The participants in the positive and negative valence conditions did not differ in their one-back performance in either age group.

Table 2: Task performance for young and older adults

<table>
<thead>
<tr>
<th>Task</th>
<th>Young Adults</th>
<th>Older Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>One-Back Accuracy</td>
<td>9.74</td>
<td>0.74</td>
</tr>
<tr>
<td>RT (ms)</td>
<td>541.74</td>
<td>92.48</td>
</tr>
<tr>
<td>Flanker Task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congruent</td>
<td>565.84</td>
<td>145.46</td>
</tr>
<tr>
<td>Incongruent</td>
<td>749.98</td>
<td>277.81</td>
</tr>
<tr>
<td>Neutral</td>
<td>579.06</td>
<td>132.59</td>
</tr>
<tr>
<td>Single</td>
<td>535.66</td>
<td>125.23</td>
</tr>
<tr>
<td>Incong-Congruent</td>
<td>184.14</td>
<td>191.71</td>
</tr>
</tbody>
</table>

Note: * p < .05  ** p < .001

Flanker Task

We analyzed RT, per participant, for each of the four types of trials: congruent, incongruent, neutral and single. These means were based on correct trials and were
trimmed for RTs that exceeded 3 SDs above or below the participant’s overall mean. Of particular interest was the difference in RT between incongruent and congruent trials. This represents the cost of distracting flanker arrows, with smaller differences corresponding to greater cognitive control and a better ability to ignore irrelevant information. We then categorized participants based on their incongruent minus congruent RT into high and low cognitive control groups. Those who scored above the median RT for their age group were determined low in cognitive control, and those who scored below the median were identified as high in cognitive control.

Overall, younger adults were faster on congruent \( (F(1,62) = 25.25, p < .001) \), incongruent \( (F(1,62) = 20.10, p < .001) \), neutral \( (F(1,62) = 22.14, p < .001) \) and single trials \( (F(1,62) = 18.78, p < .001) \) compared to older adults (see Table 2). Older adults were more susceptible to distraction, as revealed by the larger difference in RT between incongruent and congruent trials \( (F(1,62) = 7.15, p = .010) \). Again, there was no significant effect of valence group (or interaction) on these flanker task measures.

*Implicit Priming*

Baseline completion rates were first established for emotional and neutral counterbalance lists, across age groups and valence types (Table 3). Baseline rates were determined by computing the average percentage of fragments completed by participants when the words were new and not seen during the one-back picture task. Emotional and neutral priming scores for each participant were calculated as the difference between the target completion rates and baseline completion rates for the same word lists.

**Table 3: Baseline completion rates for positive, negative and neutral words across age groups**

<table>
<thead>
<tr>
<th></th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>0.33</td>
<td>0.28</td>
<td>0.29</td>
</tr>
</tbody>
</table>
**Priming for negative and neutral words.** Overall, priming for negative words in young (t(16) = 2.69, p = .016) and older adults significantly differed from zero (t(15) = 2.95, = .01) but no priming was observed for neutral words (Figure 1).

![Figure 1: Mean rate of negative and neutral priming across age groups. Error bars represent standard error of the mean. Bars with an asterisk indicate that priming significantly differed from zero (p<.05).](image)

We conducted a 2 (age: young, old) X 2 (time of testing: morning, afternoon) X 2 (emotional: emotional, neutral priming) ANOVA with emotion as a repeated measure. None of the main effects or interactions were significant. However, the main effect of emotion approached significance (F(1, 29) = 3.66, p = .066), with priming for negative words (M = .11, SD =.16) being greater than priming for neutral words (M = .05. SD =.18). The interaction of emotion by age group by time of testing also had a trend towards significance (F(1,29) = 3.01, p = .09). Young adults tended to have higher priming for neutral and negative words in the morning than in the afternoon (see Table 4). Older adults tended to show greater priming for neutral words in the afternoon and similar priming for negative words in the morning or afternoon.

<table>
<thead>
<tr>
<th></th>
<th>Older Adult Priming</th>
<th>Young Adult Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>0.12</td>
<td>0.10</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.04</td>
<td>0.06</td>
</tr>
</tbody>
</table>

**Table 4: Priming rate for neutral and negative words in morning and afternoon test sessions across age groups**
The influence of cognitive control for priming in the negative valence condition was analyzed with repeated measures ANOVA. Age (young, older), time of testing (morning, afternoon) and cognitive control (high, low) were between subjects factors, and emotion (emotional, neutral) was a within subjects factor. There was a significant 3-way (emotion by time of testing by cognitive control, $F(1,25) = 12.48, p = .002$) and 4-way interaction (emotion by age by time of testing by cognitive control, $F(1,25) = 7.09, p = .013$). However, due to the very small number of participants in some of the cells in this analysis, we were unable to draw firm conclusions from these interactions. Since time of day was not a significant factor in the initial repeated measures analysis, we collapsed results across morning and afternoon test sessions to further examine the influence of cognitive control. No main effects were significant but a significant interaction for age by cognitive control was found ($F(1,29) = 5.73, p = .023$). Younger participants with high cognitive control had higher priming rates for negative words ($M = .14$, $SD = .14$) than those with low cognitive control ($M = .05$, $SD = .14$). The opposite was found for older adults: participants with low cognitive control had higher priming for negative words ($M = .15$, $SD = .14$) than those with high cognitive control ($M = .01$, $SD = .14$). Figure 2 shows this effect, as well as the finding that neutral priming increased along with negative word priming in high cognitive control young adults and low cognitive control older adults.
Figure 2: Mean negative and neutral priming rates for young and older adults across high and low cognitive control. Error bars represent standard error of the mean.

*Priming for positive and neutral words.* Priming for positive and neutral words in young and older adults did not differ from zero (Figure 3). There was a trend towards higher rates of priming for positive words in older adults ($t(15) = 2.09$, $p = .056$).

Repeated measures ANOVA revealed no main effects for emotion, age or time of day on priming rates for positive/neutral words, as well as no significant interactions (Table 5). To assess whether cognitive control influenced priming a 2 (age: young, older) X 2 (time of testing: morning, afternoon) X 2 (cognitive control: high, low) X 2 (emotion: positive, neutral) ANOVA was performed.
emotional, neutral) ANOVA with emotion as repeated measure was conducted. Once again, no significant main effects or interactions were found.

Table 5: Priming rate for neutral and positive words in morning and afternoon test sessions across age groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Neutral</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>0.06</td>
<td>0.21</td>
</tr>
<tr>
<td>Afternoon</td>
<td>-0.02</td>
<td>0.17</td>
</tr>
<tr>
<td>Old</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>0.05</td>
<td>0.21</td>
</tr>
<tr>
<td>Afternoon</td>
<td>0.05</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Figure 4: Mean positive and neutral priming rates for young and older adults across high and low cognitive control. Error bars represent standard error of the mean.

Since time of day was not a significant factor in positive and neutral priming the repeated measures ANOVA was re-run without this variable (as was done for the negative/neutral group above, Figure 4). Results showed a trend for an age by level of cognitive control interaction (F(1,29) = 2.23, p= .147). Older adults with high cognitive control tended to show greater priming (M = .15, SD = .22) than those with low cognitive control (M = .01, SD = .22), whereas younger adults showed little evidence of priming regardless of cognitive control level (high M = .01, SD = .23; low M = .03, SD = .22). Similar to the negative valence condition, neutral priming increased along with positive priming for older adults classified as high in cognitive control.
Discussion

The present study investigated age-differences in implicit memory for emotional and neutral words. Unlike some explicit memory studies, we did not observe a general enhancement of memory for positive information in older adults (Kennedy et al., 2004; Charles et al., 2003; Mather & Carstensen, 2003). Priming for negative words in young and older adults significantly differed from zero, while positive and neutral priming did not. This suggests that age differences in emotional memory may not be due to a deficit in processing negative information, since younger and older adults were equally likely to show priming for negative words. This result would be consistent with SST, which suggests that age differences in emotional memory arise when there is the opportunity for cognitive resources to implement emotional goals.

The opportunity to use emotion regulation during an implicit memory task was hypothesized to be dependent on a person’s level of cognitive control. Consistent with our hypothesis and the SST, cognitive control influenced positive and negative word priming. Older adults with high cognitive control had a trend towards greater priming in the positive valence condition, whereas younger adults with high cognitive control had greater priming in the negative valence condition. Although the results for priming of positive words and cognitive control were not significant, the fact there was a trend reported with the small number of participants is noteworthy. In terms of participants with low cognitive control, older adults had higher priming rates in the negative valence condition, whereas younger adults had similar priming rates across valence types. Regulation of emotion is an important goal for older adults. Results seen here suggest that older adults with high cognitive control can use these resources in service of their
emotional goals to reduce priming or interference from negative words and enable positive words to be more accessible. However, older adults low in cognitive control would be less able to expend resources to regulate emotions and would have reduced inhibition of negative words, allowing them to have a greater influence on priming. These results are consistent with Mather and Knight’s (2005) proposal that emotion regulation goals in older adults are chronically available, even at an unconscious level.

It was previously thought that young adults do not engage emotion regulation processes to the same extent as older adults, but our findings suggest that negative information is just as important to young adults as positive information is to older adults. If emotion regulation was not related to younger adults’ performance than young adults should show greater priming for negative words irrespective of their level of cognitive control, but this was not the case. Priming for negative words was greater for younger adults with high cognitive control. Therefore, the negativity effect (better memory for negative versus positive information; for review see Murphy & Isaacowitz, 2008) commonly observed in young adults may be driven by goal-oriented processes. These results extend the SST to young and older adults, by demonstrating that both age groups are influenced by unconscious emotion regulation goals and that only those with high cognitive control are able to execute them during an implicit memory test.

There are two possible reasons as to why young adults low in cognitive control showed no differences between negative and neutral priming: (1) distraction towards negative information is greater for younger adults and (2) emotion regulation strategies are not as efficient in younger adults. Younger adults have been shown to have greater difficulty than older adults disengaging and inhibiting negative stimuli (Hahn et al., 2006;
Mather & Carstensen, 2003). If younger adults are more distracted by negative information then they would show priming for negative words, even at times when they cannot implement goal oriented processes. Also, the ability to regulate emotions is different across age groups. A study found that regulating negative emotions was more costly to working memory performance in younger adults, whereby the performance of older adults’ was unaffected (Scheibe & Blanchard-Fields, 2009). It appears that older adults are better able to regulate their emotions, and consequently, need fewer resources to do so. Nevertheless, the one-back task executed by participants in the current study was cognitively demanding. It required participants to make picture comparisons and to ignore distracting emotional words. Those with high cognitive control would be able to use their resources to ignore words that were not emotionally relevant, whereas those with low cognitive control may be less able to regulate distracting emotional words and may have allowed positive and negative information to be equally accessible.

Cognitive control influenced emotional processing in similar studies assessing recall and attention. Mather and Knight (2005, Experiment 2) found that high cognitive control older adults had better memory for positive items and young adults for negative items. We also found that older adults with low cognitive control showed greater priming for negative words. Knight and colleagues (2007) found comparable results when examining age differences in eye fixations to pictures. During a full attention condition older adults attended to positive pictures, but during divided attention, when cognitive resources were reduced, older adults fixated more on negative pictures. Younger adults had greater fixations to negative pictures during the full attention and reduced fixations during the divided attention task.
A commonality between the present study and Knight et al’s (2007) was that both used emotional and neutral lists (homogenous valence), rather than lists containing positive, negative and neutral items (heterogeneous valence). The arrangement of emotional and neutral information can affect the way information is processed. Displaying positive and negative words during encoding has been found to eliminate age differences across valence types (Knight et al., 2007; Gruhn et al., 2005). Knight and colleagues (2007) argued that by presenting positive and negative items together, the lack of variation in arousal causes there to be greater interference and competition among emotional items. Another possibility is that the order of positive and negative information may affect the way subsequent words are processed. For instance, a negative word might be perceived as more negative if presented with positive words, changing the valence and meaning of stimuli (Gruhn et al., 2005). The study by Mather and Knight (2005) presented positive and negative pictures alongside neutral pictures, which could have reduced the affect of cognitive control. Our study is consistent with the idea that using homogeneous lists can enhance age differences in memory for emotional material.

An interesting finding was that high cognitive control participants had greater priming for neutral words when they were presented with affective words that reflected their emotional goals. For example, young participants with high cognitive control had higher rates of neutral priming only when paired with negative words; while, older adults with high cognitive control had higher rates of neutral priming when paired with positive words. Separate processes may account for the carry-over effects observed in neutral priming for young and older adults.
For instance, recall from lists that have positive, negative and neutral words show strong contextual effects in younger but not older adults (Gruhn et al., 2005). Younger adults had greater recall for negative and neutral words, and lower recall of positive words, when the words were presented together versus when they were presented separately. Gruhn and colleagues (2005) argue that these contextual effects in young adults are driven by the greater prioritization that young adults place on negative information. Nevertheless, their argument does not account for why priming for neutral information would be increased when neutral items are presented along with negative ones.

Contrary to younger adults, older adults show greater priming for neutral words when presented along-side positive words. Fredrickson’s (2001) “broaden and build theory” proposes that positive emotions from an evolutionary perspective are meant to broaden an individuals thought action repertoires. Consistent with this theory, positive mood induction causes a broadening of attentional focus or a relaxation of inhibitory control (Rowe, Hirsh, & Anderson, 2007; Fredrickson & Branigan, 2005). Reduced inhibition during the presentation of positive words would enable neutral words to be processed as well. This would explain why older adults show greater priming for neutral words during the positive valence condition.

It is quite possible that this broadening of attentional focus may only occur when information is emotionally relevant, regardless of whether it is positive or negative. The attentional-load theory argues that perceptual load required for a primary task determines the amount of resources available for processing irrelevant information (Lavie, 1995). The less attention needed to complete the primary task, the more resources that can be
given to attend to irrelevant information. Based on this premise, high cognitive control participants would have more resources available on the one-back task to attend to emotional goals. We suggest that having high cognitive control would make the one-back task easier and lead to a relaxation of inhibitory control, enabling inhibition to be decreased and priming increased for both emotional and neutral words.

Priming in the morning and afternoon test sessions also differed across participants, specifically priming in the negative valence condition. Priming for negative items may have been more affected by time of testing since it was the only valence that showed significant priming across age groups. Priming for negative and neutral words was higher in the morning for young adults. Older adults, on the other hand, had higher neutral priming in the afternoon and similar priming for negative words across the day. Research has shown that those classified as evening type individuals are more susceptible to distraction in the morning, and morning type individuals are more susceptible to distraction in the afternoon (Yang et al., 2007; May et al., 1993; May & Hasher, 1998). Young participants most likely had greater priming in the morning due to the fact that the morning is frequently reported as young adults off peak time of day. Contrary to younger adults, older adults were expected to have increased priming in the afternoon, usually considered their off peak time of day. This was the case for neutral priming but not for priming for negative words. One possible reason for the discrepancy could be that our participants were made up of more neutral rather than morning or evening type people. This could have swayed priming by time of day effects depending on whether the neutral type participants would be considered more on the morning or evening side of the spectrum.
Conclusion

Implicit memory for emotional words was similar across age groups, with both young and older adults exhibiting priming for negative words. The finding that cognitive control influences priming adds to the SST, which states that emotion regulation is an important factor that contributes to older adults’ memory for emotional content. It also extends the SST view to younger adults, by suggesting that young adults process negative information in a goal consistent manner similar to older adults. In addition, contextual effects for priming of neutral words were observed under conditions that promoted emotional goals. Future research, however, would need to be conducted to examine to what extent contextual effects are driven by a broadening of attentional resources.
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