

**The cognitive control of emotional versus value-based information
in younger and older adults**

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Abstract

We investigated age-related changes in the cognitive control of value-based and emotionally-valenced information. In two experiments, participants completed a selectivity task in which to-be-recalled words differed in value and emotional salience. In Experiment 1, all low-valued words were emotional, and emotional valence (positive/negative) was manipulated between-subjects. In Experiment 2, valence was manipulated within-subjects, with the addition of a control condition in which all words (emotional and neutral) were equally valued. We found that older and younger adults recalled more neutral words than emotional words in both experiments when emotional words were low-valued and more emotional words than neutral words in the control condition. Emotion did not interact with age in either experiment, suggesting that the impact of emotional saliency on memory is age-invariant. We also found that the number of items recalled was lower for older compared to younger adults in both experiments. Despite this, older and younger adults showed equivalent selectivity in terms of which words they recalled. These results suggest that older adults can employ strategic control and use value-based information to guide memory processes equivalently to younger adults, even in the face of salient emotional information.

Keywords: memory, aging, emotion, and cognitive control, value

Word Count: 5,703

It is well established that the ability to encode and retrieve information declines with age (Kester, Benjamin, Castel, & Craik, 2002). Not all cognitive processes exhibit such trajectories, however (Hasher & Zacks, 2006). Emotion regulation, for example, has been shown to be preserved in aging (Blanchard-Fields, 1986). The interaction between these different types of processes, including how aging affects memory for and cognitive control of emotional information, is not yet well understood.

The value-directed remembering (VDR) paradigm (Castel, 2008; Castel, Benjamin, Craik, & Watkins, 2002) is a point-based selectivity task that has been used to assess how individuals cognitively control memory. In the VDR paradigm, participants are presented with lists of word-number pairs, and are instructed to remember as many words as they can in order to maximize their score, calculated as the sum of the point values associated with correctly recalled words. The VDR provides traditional indexes of memory performance, including the number of words recalled and score. It also allows for the computation of a metric of how efficiently individuals cognitively control which items to encode and recall, called the Selectivity Index (SI) ratio (Watkins & Bloom, 1999). SI compares the participant's recall score to the highest score they could have attained given the number of words they recalled (their "ideal" performance), relative to chance performance. If a participant recalled four words out of a possible twelve, for example, ideal performance would be recalling the four highest-valued words. Chance score is based on the average possible point value for the list multiplied by the number of words recalled. Thus, if a participant recalled the words associated with the 12, 10, 9, and 8 point values, that participants' SI would be considered quite high. The ideal score for four words is $12 + 11 + 10 + 9 = 42$, chance score is $26 (6.5 * 4)$, and their actual score is 39; SI in this case is $(39 - 26) / (42 - 26)$.

26) = .81. SI can range from 1 to -1. Perfect selectivity results in an SI of 1.0, whereas selection of words with the lowest values (e.g., recalling the 1-, 2-, 3- and 4-point words) would result in an SI of -1.0. A set of words recalled with no regard to point value (i.e., showing no selectivity) would result in a selectivity index close to 0. Castel et al. (2002) found that, although the number of items recalled and scores were greater for younger relative to older adults, older adults performed equivalently to younger adults when baseline rates of recall were controlled for using this selectivity index. That is, although younger adults recalled more words overall, older and younger adults showed equivalent rates of recalling higher point value words, and thus demonstrated similar strategic control of memory.

Multiple variants of the VDR paradigm have been used to target different aspects of cognitive control, and the results suggest that older adults maintain the ability to cognitively control encoding and retrieval processes (see Castel, McGillivray, & Friedman, 2012 for a review). However, what happens when low-valued items in the VDR paradigm are made to be emotionally salient? Younger adults have been shown to recall/recognize emotional information, particularly when negatively-valenced, to a greater degree than non-emotional information (Buchanan & Adolphs, 2002), a finding thought to result from the information's perceptual salience (Mather, 2007). Indeed, results from many studies suggest bottom-up, prioritized processing of emotional information (Anderson, 2005; Anderson & Phelps, 2001; Clark-Foos & Marsh, 2008; Reisberg & Heuer, 2004; Vuilleumier & Driver, 2007). Thus, in a VDR task in which the lowest-valued words are highly salient, top-down cognitive control over goal-relevant value-based information (remembering as many of the highest point-valued words in order to achieve the highest score) must compete with bottom-up processing (the automatic encoding of

salient emotional information). When this is the case, will older adults still be able to cognitively control memory processes?

Previous work has suggested age-related differences in the way that emotional information influences memory. In some studies, older adults show a “positivity bias”, and are either less responsive to negative emotional outcomes than are younger adults (Grühn, Scheibe, & Baltes, 2007; Wood & Kisley, 2006) or lack the negativity bias typically seen in younger adults (Ito, Larsen, Smith, & Cacioppo, 1998). Leclerc and Kensinger (2008) found that older adults exhibited a positivity effect in memory for words (but not for pictures). Other studies have reported that older adults are biased towards positive information, selectively attending more to positively-valenced information over neutral and negative information relative to younger adults (Mather & Carstensen, 2005). The results of subjective report studies, for example, found that older adults perceive both minor distress (daily stressors; Almeida, 2005) and major distress (bereavement; Lichtenstein, Gatz, & Berg, 1998) with less negative reactivity than younger adults. Similarly, older adults have been shown to have more positive, emotionally gratifying memory distortions for past choices (Kisley, Wood, & Burrows, 2007; Mather & Carstensen, 2005; Mickley-Steinmetz, Muscatell, & Kensinger, 2010; Wood & Kisley, 2006). However, the positivity effect is not always seen (Denburg, Buchanan, Tranel, & Adolphs, 2003; Leshikar, Dulas, & Duarte, 2015) and there has been increasing interest in clarifying the sets of circumstances that result in its occurrence (Kensinger, 2009; Murphy & Isaacowitz, 2008).

Studies assessing how attention is mediated by visual emotional information suggest age-invariance in older and younger adults ability to detect emotional as opposed to non-emotional information amongst distractors in a visual search task (Hahn, Carlson, Singer, & Gronlund, 2006; Leclerc & Kensinger, 2008; Mather & Knight, 2006). Mickley-Steinmetz, Muscatell and

Kensinger (2010) found that attention to information that was temporally proximate to emotional information was equivalent for both older and younger adults. Another series of studies by Kensinger and colleagues showed that older adults, like younger adults, exhibited a memory enhancement effect for negative as compared to positive and neutral items: older adults remembered item-specific negative details equally well as younger adults and were more successful at distinguishing between item exemplars when the items were negative versus positively-valenced (Kensinger, Garoff-Eaton, & Schacter, 2006, 2007a, 2007b, 2007c). Further, a recent report by Depping and Freund (2013) showed in two experiments that older adults recalled more negative information than neutral and positive information, and recalled more negative information than did younger adults in a choice-based incidental memory paradigm. The results of these studies suggest that emotion influences memory and attention in a similar, or perhaps even an enhanced manner across the lifespan.

In order to investigate the relationship between emotion and the cognitive control of memory we tested healthy older and younger adults on an emotional version of the VDR paradigm. In the first experiment, participants were presented with lists of words, each containing 12 word-number compounds. The number indicated the word's value, ranging from 1-12. Critically, the lowest four point-values were paired with emotional words: either negatively- or positively-valenced, between subjects, while the remaining eight higher point-valued words were neutral. In the second experiment, the valence of the words was manipulated within-subjects rather than between, and, additionally, a control condition in which all words (negative, positive, and neutral) were paired with the same point value was included. This control condition allowed us to assess emotional memory when cognitive control over salient emotional information was not required. In both experiments, we chose to present eight neutral

items and four emotionally-valenced items (a two-thirds neutral/one-third emotional valence item split) so that we could be more confident that recall of the emotional items was due to the item's salience, rather than because individuals had sufficient working memory capacity to also encode these lower-valued items. Normal working memory span capacity limits are estimated to range from 3-5 (Cowan, 2010) to 6-8 (cf. Miller, 1956) in younger adults. Age-related declines in working memory span --the amount of information that can be stored and processed simultaneously-- have frequently been reported (Charness, 1987; Gick, Craik, & Morris, 1988; Salthouse, 1988). Thus, had half (or six) of the items been emotional, and a participant had recalled eight items, recall due to memory capacity limits would be confounded with recall due to the word's saliency. For younger adults, who have higher working memory capacities, this may have biased the results. In addition, we chose to present a fewer number of emotional words to mimic more realistic situations in which emotional information is not as omnipresent as non-emotional information. The combination of a mixed factorial designs allows us to investigate how younger and older adults reconcile competing processes: bottom-up processes that should lead to the encoding of low-valued, emotionally salient words; and top-down cognitive control processes that are required to overcome emotional saliency and encode high-valued (but neutral) words in accordance with goals (in this case to maximize score).

Experiment 1

Methods

Participants. Forty-one undergraduate students from the University of California, Los Angeles (UCLA; 27 women, 14 men, M age = 20.4, SD = 2.0), received course credit for their participation. One younger adult's age was unavailable. Twenty-one of the younger adults (15 women, 6 men, M age = 21.05, SD = 2.5) were in the negative low-value condition, while 20 (12

women, 8 men, M age = 19.75, SD = 1.1) were in the positive low-value condition. A total of forty-two older adults (24 women, 18 men, M age = 74.8, SD = 6.9) were paid to participate in the study. Twenty-one older adults (12 women, 9 men M age = 73.79, SD = 6.8) received lists containing negative low-value words, and 21 (12 women, 8 men, M age = 75.84, SD = 7.1) were assigned to the positive low-value condition. Older adults, recruited to the study through community flyer postings and established participant pools, were living independently in the community, and reported themselves to be in good health. Informed consent, conforming to APA guidelines and approved by the UCLA or Columbia University Medical School (CUMC) IRB, was obtained prior to study participation.

Materials. The stimuli were four- to ten-letter words. The materials were identical to those used by Castel et al. (2002), except that the four lowest-valued words were replaced with either positively- (M valence = 8.27, M arousal = 6.35, M dominance = 6.40, M frequency = 21.41, e.g., rainbow) or negatively-valenced (M valence = 1.94, M arousal = 5.91, M frequency = 41.31, e.g., murderer) words chosen from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999) database based upon affective arousal ratings, word length and word frequency. The words with point values 5-12 had an everyday occurrence of at least 30 times per million (Thorndike & Lorge, 1944). Eight mixed emotional and neutral lists were created (see Appendix A). Each list contained four unique emotional words (either negatively- or positively-valenced) and 8 neutral words. Emotional words were paired, at random, with values ranging from 1 to 4, while neutral words were paired, at random, with values ranging from 5 to 12. Once word-value pairs were established, the entire word order was randomized for each list, and list order was randomized.

Procedure. Participants were randomly assigned to either a negative low-value or a positive low-value condition and were tested individually. Participants were instructed to try to achieve the highest score they could by recalling as many of the high point-valued words at the end of the 8 lists, but were reminded that recalling any word would improve their score. After presentation of all 12 word-number pairs in each list, participants had 20 s to recall as many words as they could out loud while the experimenter recorded their responses. Feedback (score) was given for each list. Word-number pairs were presented in black (Times, 24 pt) in the center of a computer screen for 1 sec each.

Results

We began by examining the overall performance and selectivity of younger compared to older adults. Because the valence of the emotional words (negative versus positive) was manipulated between-subjects, we conducted separate Analysis of Variances (ANOVAs) on each group (those in the positive low-value condition, and those in the negative low-value condition). Overall scores in the positive low-value condition significantly differed between younger and older adults ($M = 34.02$ vs. 25.54 , $F(1, 39)=15.86$, $p<.001$, $\eta_p^2=.29$). The average number of items recalled across the eight lists also significantly differed between younger and older adults in the positive low-value condition, with younger adults recalling on average 4.43 items and older adults recalling 3.1 items ($F(1, 39)=33.04$, $p <.001$, $\eta_p^2=.46$). The results were similar in the negative low-value condition. Younger adults achieved higher scores than older adults ($M = 35.96$ vs. 30.17 , $F(1,40)=6.26$, $p =.02$, $\eta_p^2=.16$) and recalled more words (4.48 vs. 3.7 , $F(1,40)=9.59$, $p =.004$, $\eta_p^2=.19$). Despite these differences, selectivity, as measured by SI, did not differ between younger and older adults for either the positive ($M = .32$ vs $.39$) or negative ($M = .43$ vs $.42$) low-value conditions (both $F_s<1$).

We next investigated age-related differences in the proportion of neutral words recalled in each list (out of eight) and the proportion of emotional words recalled in each list (out of four), in each of the two conditions. In the positive condition, a repeated-measures ANOVA with Emotion (positive vs. neutral words) as a within-subject factor and Age (young vs. old) as a between subjects factor revealed a significant main effect of both Emotion ($F(1, 39)=78.54, p <.001, \eta_p^2=.67$) and Age ($F(1, 39)=36.28, p <.001, \eta_p^2=.48$). As can be seen in Figure 1A, the proportion of neutral words recalled was greater than the proportion of positive words recalled (M neutral = .39, M positive = .17), and younger adults recalled more words than did older adults (M young = .33, M neutral = .23). The interaction between Emotion and Age was not significant ($F(1, 39)<1$). Planned post hoc one-way ANOVAs revealed that younger adults recalled a significantly higher proportion of neutral words than did the older adults ($M = .44$ vs. $.33$, respectively, $F(1, 39)=14.91, p <.001, \eta_p^2=.28$). Younger adults also recalled a significantly larger proportion of positively-valenced words than did older adults ($M = .22$ vs $.12$, respectively, $F(1, 39)=11.42, p=.002, \eta_p^2=.23$).

In the negative low-value condition, the main effects of Emotion (negative vs. neutral) and Age were also significant. As can be seen in Figure 1B, the proportion of neutral words recalled was greater than the proportion of negative words recalled ($F(1, 39)=101.2, p <.001, \eta_p^2=.72, M$ neutral = .43, M negative = .18), and younger adults recalled a higher proportion of words overall than did older adults ($F(1, 39)=9.9, p =.003, \eta_p^2=.19, M$ young = .33, M old = .27). Like in the positive condition, the interaction between Emotion and Age was not significant in the negative condition. Once again, planned post hoc tests revealed that the younger adults recalled a significantly greater proportion of neutral words than did the older adults ($M = .46$ vs. $.39$, respectively, $F(1, 40)=5.95, p =.02, \eta_p^2=.13$), analogous to the results found in the positive

condition. However, the proportion of negatively-valenced words recalled by younger and older adults did not differ significantly ($M = .20$ vs. $.16$, respectively, $F(1, 40) = 1.72$, $p = .20$).

While the recall results for neutral and positive words fit well with widespread findings of age-related declines in memory, the non-significant difference between older and younger adults in the recall of negatively-valenced words represents a departure. To investigate whether the lack of a significant difference found using traditional null hypothesis testing in the proportion of negatively-valenced words recalled for younger and older adults is meaningful, we conducted Bayesian t-tests, which allows direct probability interpretations for obtaining our results under the null hypothesis H_0 (no recall difference between Ages) or the alternative hypothesis H_1 (age-related memory differences) to be made (Love et al., 2015). The Bayes Factor $(BF)_{10}$ for the neutral words in the positive condition was 64.97, and for the neutral words in the negative condition it was 3.00. BF_{10} was 20.6 for the positively-valenced words, but it was only 0.60 for the negatively-valenced words. According to Kass and Raftery (1995), BF values 3 and above provide “positive” to “strong” evidence against H_0 , while values between 1-3 are “not worth more than a bare mention.” These results suggest age-related differences in the recall of neutral (regardless of condition) and positively-valenced words, but age invariance in the recall of negatively-valenced low-valued words. Indeed, from BF_{01} (the log of BF_{10}) it can be seen that the negative valence results obtained here are nearly 1.67 times more likely to have occurred under H_0 than H_1 .

Discussion

In Experiment 1, we found that older adults in both the negative and positive conditions recalled significantly fewer words and achieved significantly lower scores when compared to the younger adults. We also found that Emotion did not interact with Age in either the positive or

negative condition, suggesting that emotional information has similar effects on older and younger adults' memory. When we probed further, however, we found that older and younger adults differed in the proportion of positive and neutral words recalled, but not of negatively-valenced words, suggesting that if anything, older adults demonstrate a negativity bias. Our results also demonstrated that cognitive control over encoding, indexed using SI, was equivalent for the younger and older adults in both conditions. In the face of salient positive and negative valenced emotional information known to exhibit automatic bottom-up influences on attention, and subsequently on memory, older adults were equally able to cognitively control memory-encoding operations.

Experiment 2

Experiment 1 demonstrated that, although older adults exhibited declines in recall rates and score relative to younger adults, their ability to cognitively control memory in the face of emotionally salient information was preserved. Further, the results suggest that the effect of emotional information on memory is equivalent between older and younger adults. However, as Experiment 1 manipulated the valence of the emotional words between subjects, we could not directly compare the effects of negative versus positive valence on memory and cognitive control either across younger and older adults, or within each age group. There was also no control condition, and thus there is the possibility that baseline differences in the encoding of positively- or negatively-valenced information between young and older adults may have contributed to the results.

In Experiment 2, we attempted to resolve these issues. We had two main questions. First, when cognitive control is not required, do baseline rates of recall for emotional versus neutral items differ for older and younger adults, and are these affects mediated by the valence of

the information? To address this question, in Experiment 2 we included a control condition that was identical to the experimental conditions in Experiment 1 (containing four emotionally words and eight neutral words), except that all words were worth 12 points; thus, every word was high reward. These control tasks provide a way of measuring the saliency of the emotional words used in the current paradigm and its interaction with age, without processes involved in cognitive controlling bottom-up processes triggered by that saliency. Second, we could investigate whether the age-related effects found in Experiment 1 remain when lists containing both negatively and positively-valenced words were included in one model. As Experiment 1 was a between-subjects design, we could not directly investigate this question. Thus, in Experiment 2, participants were given both positive-low value and negative-low value word lists, which allows for a direct comparison between negatively-valenced, positively-valenced, and neutral words.

Methods

Participants. Twenty-one younger adults (15 women, 6 men, M age = 25, SD = 3.6) and 22 older adults (9 women, 13 men, M age = 67.4, SD = 3.7) completed the study. All participants were living independently in the community and reported themselves to be in good health. Education level did not differ between older and younger adults ($t(41) < 1$). Informed consent, conforming to APA guidelines and approved by the CUMC IRB, was obtained prior to study participation.

Materials. The stimuli were three- to twelve-letter words. Thirty-two positively-valenced words (M valence = 8.31, M arousal = 6.35, M dominance = 6.37, M frequency = 38.06), thirty-two negatively-valenced words (M valence = 1.76, M arousal = 6.29, M dominance = 3.5, M frequency = 23.9), and 128 neutral words (M valence = 5.21, M arousal = 4.07, M dominance = 5.01, M frequency = 76.14) were chosen from the ANEW database.

Procedure. Each participant was presented with sixteen lists of words (see Appendix B). In each list, four words were emotionally-valenced, and eight were neutral words. Eight lists were identical in form to those used in Experiment 1 (four positive-low value lists and four negative-low value lists). The remaining eight lists constituted the negative and positive control conditions in which all words, both emotional and neutral, were paired with the value ‘12’. Half of these lists contained positive and neutral words, while the other half contained negative and neutral words. Word order was randomized within list, and list order was then randomized. As in Experiment 1, after presentation of the 12 word-number pairs in each list, participants had 20 s to recall as many words as they could out loud, while the experimenter recorded their responses. The experimenter provided the participant with their score after each list. Word-number pairs were presented in black (Times, 24 pt) in the center of a computer screen for 1 sec each.

Results

We began by investigating performance in the control conditions in which all words were paired with the same point value. A univariate ANOVA revealed that younger adults recalled more words than did older adults ($F(1, 41)=17.43, p < .000, \eta_p^2=.29, M_{\text{young}} = 4.89, M_{\text{old}} = 3.92$ words), and, thus, necessarily had higher scores, as all words were paired with the value ‘12’ ($M_{\text{young}} = 56.64, M_{\text{old}} = 46.98$). We next examined the proportion of neutral and emotional words recalled in the control condition. A repeated-measures ANOVA with Age (young vs. old) as a between subjects factor and Emotion (emotional vs. neutral words) and Valence (negative vs. positive) as within-subjects factors revealed a significant main effect of Emotion ($F(1, 41)=4.58, p = .04, \eta_p^2=.1$), such that emotional words were recalled proportionally more than neutral words ($M_{\text{emotional}} = .40, M_{\text{neutral}} = .34$), and a main effect of Age, such that younger adults recalled a higher proportion of words overall relative to older adults ($F(1,$

41)=5.47, $p < .024$, $\eta_p^2 = .12$). The main effect of Valence was not significant ($F(1, 41) = 2.91$, $p = .01$), nor were any of the interactions: Emotion x Age ($F(1, 41) = 1.43$, $p = .24$), Valence x Age ($F(1, 41) < 1$), Emotion x Valence ($F(1, 41) = 2.91$, $p = .01$), and Emotion x Valence x Age ($F(1, 41) < 1$). These results indicate that emotional words were recalled to a greater extent than neutral words, and that the emotional saliency of the words impacted older and younger adults similarly.

We next turned to the experimental conditions, in which the lowest four point-values were paired with negatively- and positively-valenced words, while the middle and higher point-valued words were neutral. As was the case in Experiment 1, the number of items recalled differed as a function of age, with younger adults recalling more words than older adults ($F(1, 41) = 16.79$, $p < .001$, $\eta_p^2 = .29$, $M_{\text{young}} = 4.58$, $M_{\text{old}} = 3.50$). Unlike in Experiment 1, older and younger adults did not differ in terms of their scores ($F(1, 41) < 1$). The analysis of SI replicated the results of Experiment 1: we found no difference between younger and older adults ($F(1, 41) = 1.4$, $p = .24$; $M_{\text{young}} = .46$, $M_{\text{old}} = .56$).

Finally, we investigated the proportion of words recalled by younger and older adults as a function of both Emotion and Valence. A repeated-measures ANOVA with Age as a between-subjects factor and Emotion and Valence as within-subjects factors revealed a main effect of Emotion, such that the proportion of neutral words recalled was higher than the proportion of emotional words recalled ($F(1, 41) = 36.35$, $p < .001$, $\eta_p^2 = .47$), and a main effect of Age, such that younger adults recalled more words than did older adults ($F(1, 41) = 7.84$, $p = .008$, $\eta_p^2 = .16$). The main effect of Valence was not significant ($F(1, 41) = 1.2$, $p = .28$). In addition, we found a significant two-way interaction between Emotion and Valence ($F(1, 41) = 7.07$, $p = .01$, $\eta_p^2 = .15$). Critically, however, and analogous to the results from Experiment 1, none of the interactions containing Age as a factor were significant (Valence x Age $F(1, 41) < 1$; Emotion x Age ($F(1,$

41)=1.8, $p = .19$); Emotion x Valence x Age $F(1, 41) < 1$). Planned post hoc tests revealed that the younger and older adults did not differ in terms of the proportion of neutral words recalled in either positive-low value lists or negative-low value lists (both $F_s < 1.2$, ns). Younger adults did, however, recall a significantly greater proportion of positively- ($F(1, 41) = 7.25$, $p = .01$, $\eta_p^2 = .15$) and negatively-valenced words ($F(1, 41) = 8.78$, $p = .005$, $\eta_p^2 = .18$) than did the older adults. Paired samples t-tests to directly compare the proportion of negatively-valenced words to positively-valenced words within each Age group revealed nonsignificant differences for both the younger adults ($t(20) = 1.7$, $p = .1$) and older adults ($t(21) = 1$, $p = .35$). These results are illustrated in Figure 1C.

Discussion

In Experiment 2, we included both an experimental condition that was manipulated within-subjects and identical in structure to the conditions in Experiment 1, as well as a control condition, in which all words (emotional and neutral) were paired with the same point value. This control condition served to test whether the emotional words were, in fact, salient; if they were, they should have been recalled at a higher rate than the neutral words. In the control condition, we did indeed find that a higher proportion of emotional words were recalled relative to neutral words.

We then examined performance in the experimental conditions. Our results indicate that older and younger adults recalled proportionally more neutral than emotional words. Age did not interact with the Valence of the information recalled, indicating that positive and negative information had equivalent effects on memory encoding for older and younger adults. When we examined older and younger adults' ability to cognitively control memory, we found no

differences in their selectivity, despite lower rates of recall in the older adults relative to the younger adults.

General Discussion

Across two experiments, we investigated the relationship between age and the strategic control over memory for neutral and emotional words. In Experiment 1, valence was manipulated between subjects, such that one group of older and younger adults received lists containing negatively-valenced low-valued words, while another group of younger and older adults received positively-valenced low-valued words. In Experiment 2, we manipulated the valence of emotional words within-subjects so that we could directly test for differences in recall as a function of valence and age. We also included a control condition, allowing us to investigate how emotional valence impacts memory when cognitive control is not required.

We found that the number of items recalled were lower for older compared to young adults in both experiments. Despite these differences, our results also demonstrated that selectivity, as measured by participant's actual performance relative to "ideal" and chance performance given the number of items recalled, was not different for younger and older adults. In the face of arousing positively- and negatively- valenced information known to produce bottom-up influences on attention and subsequently on memory, older adults were equally able to strategically control memory.

These results fit nicely with previous lines of research showing that despite the ubiquitous findings of decreased recall rates, older adults' strategic control over the contents of memory remains largely intact. Indeed, results from multiple versions of the VDR task indicate small or no age-related differences in remembering high-valued words (see Castel et al, 2012), and the results from at least two directed-forgetting paradigms, which measure the strategic

control over memory and inhibitory processes, showed that older adults performed equivalently to younger adults (Sego, Golding, & Gottlob, 2006; Zellner & Bauml, 2006). Although the items in these directed-forgetting paradigms were not emotionally valenced, the results support the idea that older adults can cognitively control memorial processes.

We also investigated the proportion of emotional and neutral words recalled in each experiment in order to look for evidence of age-related changes in both emotional processing and cognitive control over emotionally salient information. In Experiment 1, Emotion (whether the word was emotional or neutral) did not interact with Age in either the positive-low value or the negative low-value conditions. However, on closer inspection using planned post-hoc tests, we found that younger adults in the positive-low condition recalled proportionally more positive and neutral words than did the older adults in this condition. Contrastingly, while younger adults recalled proportionally more neutral words than did older adults in the negative condition, there was no difference between older and younger adults in the proportion of negative words recalled, suggesting that older adults may have a negativity bias. Applying Bayesian statistics, we found that the likelihood that older and younger group's data derived from separate groups was high for the neutral and positive words, but unlikely for the negative words.

In Experiment 2, we found that the proportion of negative and positive words recalled in the control condition, where strategic control over encoding processes was not required, was greater than the proportion of neutral words recalled; this did not differ as a function of age. These results support a large literature literature showing that emotional information is better remembered than non-emotional information (LeDoux, 1996, 2000). In laboratory studies, findings consistently show an emotional enhancement effect, such that emotional information, and particularly negative emotional information presented in multiple forms –pictures, words,

sentences, and paragraphs – is recalled or recognized to a higher degree than non-emotional information when all other factors are kept constant (Buchanan & Adolphs, 2002). Similarly, many studies have confirmed that emotionally arousing stimuli are processed disproportionately due to their perceptual salience (Mather, 2007), including when attention is limited, suggesting facilitated or prioritized processing of emotional information (Anderson, 2005; Anderson & Phelps, 2001; Clark-Foos & Marsh, 2008; Reisberg & Heuer, 2004; Vuilleumier & Driver, 2007). While it is likely that this effect stems from the salience of the emotional words relative to the neutral words given the large literature showing similar effects, it is also possible that the higher rates of recall for emotional relative to neutral words found in the control conditions occurred because the emotional words were more distinctive (as they represented only 1/3 of the words in each list) rather than because of their emotional content. However, even if this is the case, we found no interactions between age and the valence of the words recalled. Thus, regardless of the cause, these results suggest that the emotional information in the current study affected younger and older adults similarly.

In the experimental condition of Experiment 2, we found that the proportion of words recalled given both whether the word was emotional or neutral, and more specifically whether the emotional words were negatively or positively-valenced, did not interact with age, suggesting that the processes that allow for the inhibition of emotional information, or the added attention given to encode neutral information, is not affected by age after controlling for baseline differences in working memory capacity. These results, coupled with the findings from Experiment 1 in which older and younger adults did not differ significantly in terms of recall of negatively-valenced words, are surprising given the work of Mather and Carstensen (2005), which suggests an age-related positivity bias. Socioemotional selectivity theory posits that, as

people age and have fewer years to live, motivational changes occur such that positively-valenced information is prioritized to a greater degree than neutral and negative information. This theory predicts that older adults show increased recall rates for positive emotional words relative to younger adults, and lower recall rates of negatively arousing emotional words relative to younger adults. We did not find evidence for a positivity effect, however, in either experiment. Further, in Experiment 1, we found evidence that older adults may have a negativity bias (based on younger and older adults equivalent rates of recall of negatively-valenced information, but nonequivalent rates of neutral and positive information). Several possibilities may shed light on our results.

First, according to Mather and Knight (2005), the positivity bias is most apparent in conditions of full attention, but it is diminished in conditions in which attention is divided, such as when participants are given a memory task concurrent with a cognitively demanding distractor task. The added top-down control component inherent to the VDR paradigm may be mimicking the effects of a distractor task for the older adults, masking a positivity bias.

Second, contrary to the findings of Mather and Carstensen (2005), but consistent with the results of Kensinger et al. (2007c), older adults may have a preserved negativity bias. Although we found some evidence in Experiment 1 for a negativity bias in older adults, who showed equivalent rates of recall of negatively-valenced words to younger adults, we did not find such an effect in Experiment 2. However, it is important to note what might be a critical difference between the two experiments. In Experiment 1, emotionality was manipulated between-subjects, such that participants in the negative-valence condition only received lists containing negative and neutral words, and did not receive positive words. Thus, the non-replication of the effect in Experiment 2 may be driven by the combination of word valence in the same paradigm. As is

often the case in studies of emotion, the negative emotion information may be stronger in nature relative to positive emotion information, and this may be particularly true when positive information is not present, as was the case in Experiment 1 but not in Experiment 2. Despite efforts to control for arousal, future work could extend these findings using pictures or other forms of emotional information, lists that contain both negatively- and positively-valenced words in addition to neutral words, and when people must interpret and recall ambiguous memories (cf., Mikels & Shuster, 2015).

Conclusions

In summary, the present study examined potential age-related changes in the cognitive control of value-based and emotional information. Our results suggest that, in the present task, older adults do not show differential memory for positive or negative information relative to younger adults and that older adults maintain cognitive control over memory, even when bottom-up emotionally salient information is pitted against goal-relevant information. Further research is needed to examine how strategic control may differ from more stimulus-driven effects, and if goals, working memory, and attention control may influence some of these effects of cognitive control over emotional information.

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Appendix A

<u>LIST 1</u>	<u>LIST 2</u>	<u>LIST 3</u>	<u>LIST 4</u>
Book 5	Stick 10	Fat/Miracle 4	Drain 11
Train 9	Hostage/Triumphant 3	Burial/Cheer 1	Plate 8
Hurt/Affection 2	Moss 7	Dwarf 8	Assault/Vacation 3
Wagon 6	Prize 5	Skull 12	Grill 7
Nest 11	Dime 8	Straw 9	Jail/Promotion 4
Loneliness/Champion 1	Smoke 12	Debt/Win 3	Aunt 10
Mail 7	Misery/Comedy 2	Tile 10	Harp 5
Berry 12	Bulb 11	Pilot 6	Crucify/Cash 1
Cruel/Laughter 3	Detest/Treasure 4	Maggot/Millionaire 2	Snow 9
Cabin 8	Tent 6	Siren 11	Fence 6
Drill 10	Afraid/Romantic 2	Valve 5	Movie 12
Bomb/Paradise 4	Oven 9	Spice 7	War/Joyful 2
<u>LIST 5</u>	<u>LIST 6</u>	<u>LIST 7</u>	<u>LIST 8</u>
Poison/Humor 2	Shoe 7	Brook 12	Tree 9
Rebel 11	Ulcer/Graduate 4	Dream 9	Hobby 6
Snake 6	Trap 11	Killer/Kiss 4	Rape/Valentine 1
Fairy 10	Sick/Lucky 3	Court 8	Salad 5
City 7	Peach 12	Nail 5	Death/Acceptance 2
Trauma/Excellence 1	Hymn 6	Poem 11	Waist 8
Lady 8	Grief/Thrill 1	Steak 6	Pollute/Ecstasy 3
Rotten/Terrific 4	Camp 9	Drown/Pleasure 2	Chief 11
Seat 12	Beast 5	Bench 10	Pump 7
Cream 9	Murderer/Joke 2	Weed 7	Thief/Confident 4
Devil/Delight 3	Mist 8	Failure/Sweetheart 1	Plea 10
Stump 5	Cloth 10	Sad/Rainbow 3	Truck 12

Appendix B

<u>LIST 1</u>		<u>LIST 4</u>		<u>LIST 7</u>		<u>LIST 10</u>	
utensil	6	umbrella	12	news	12	locker	12
disaster	4	murderer	12	table	12	ulcer	12
concentrate	12	jail	12	thermometer	12	violin	12
rabies	1	fork	12	rainbow	12	hard	12
paper	11	cabinet	12	pencil	12	hatred	12
golfer	8	misery	12	cannon	12	theory	12
army	5	name	12	joyful	12	history	12
cork	10	suicide	12	nun	12	appliance	12
chair	9	door	12	happy	12	hospital	12
iron	7	machine	12	comedy	12	rape	12
suffocate	2	fabric	12	odd	12	disloyal	12
terrible	3	column	12	sphere	12	hay	12
<u>LIST 2</u>		<u>LIST 5</u>		<u>LIST 8</u>		<u>LIST 11</u>	
success	2	seat	8	jug	12	joy	12
bowl	11	storm	11	laughter	12	month	12
windmill	5	boxer	7	doctor	12	stomach	12
treasure	3	rejected	4	chin	12	foot	12
material	12	clock	12	triumphant	12	valentine	12
rough	8	cruel	2	lamp	12	museum	12
avenue	9	tank	5	serious	12	glass	12
rattle	6	toothache	1	hairdryer	12	vacation	12
victory	1	tease	9	baby	12	love	12
ankle	10	infection	3	office	12	dark	12
bathroom	7	lawn	10	vest	12	banner	12
champion	4	metal	6	proud	12	egg	12
<u>LIST 3</u>		<u>LIST 6</u>		<u>LIST 9</u>		<u>LIST 12</u>	
part	12	writer	9	elevator	11	elbow	12
spray	12	win	3	poison	4	black	12
terrorist	12	ship	6	ink	8	headlight	12
manner	12	item	7	slave	2	lucky	12
pig	12	finger	8	mantel	5	curtains	12
time	12	paradise	4	engine	10	kiss	12
nightmare	12	noisy	11	tower	12	paint	12
arm	12	square	12	icebox	6	jelly	12
body	12	miracle	2	street	7	thrill	12
tragedy	12	passage	10	drown	3	board	12
hammer	12	cash	1	truck	9	pleasure	12
killer	12	cord	5	betray	1	lantern	12

<u>LIST 13</u>		<u>LIST 14</u>		<u>LIST 15</u>		<u>LIST 16</u>	
kettle	12	wagon	8	industry	5	butter	10
hurt	12	basket	10	yellow	8	beach	4
journal	12	fun	4	slaughter	2	statue	7
dead	12	affection	3	tool	7	rain	9
rock	12	poster	9	farm	11	humor	3
context	12	cow	5	lightbulb	9	lion	5
stove	12	cheer	1	cancer	4	trunk	11
mutilate	12	scissors	6	torture	3	promotion	1
failure	12	millionaire	2	method	6	terrific	2
hairpin	12	razor	11	radiator	12	hat	8
taxi	12	volcano	12	abuse	1	detail	6
building	12	quiet	7	glacier	10	stiff	12

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Figure 1. Proportion of recalled words for the younger and older adults. The top panel represents performance for Experiment 1, in which participants were assigned to either the **(A)** positive low-value condition where the words with point values 1-4 were positively-valenced, and words with values 5-12 were neutral or **(B)** the negative low-value condition (where the words with point values 1-4 were negatively-valenced, and words with values 5-12 were neutral). The bottom panel **(C)** represents performance for Experiment 2, in which all participants received positive and negative conditions. Error bars indicate S.E.M

