

The Cognitive Control of Emotional Versus Value-Based Information in Younger and Older Adults

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We investigated age-related changes in the cognitive control of value-based and emotionally valenced information. In 2 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 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, cognitive control, value

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 12, for example, ideal performance would be recalling the four highest valued words. Chance score is based on the average 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 $26 (6.5 \times 4)$, and their actual score is 39; SI in this case is: $(39 - 26)/(42 - 26) = .81$. 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 an SI 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 SI. 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

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items in the VDR paradigm are made to be emotionally salient? Younger adults have been shown to recall and recognize emotional information, particularly when negatively valenced, to a greater degree than nonemotional information (Buchanan & Adolphs, 2002), a finding thought to result from the information's perceptual salience (Mather, 2007). Indeed, results from numerous 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 toward 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; 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 nonemotional information among distractors in a visual search task (Hahn, Carlson, Singer, & Gronlund, 2006; Leclerc & Kensinger, 2008; Mather & Knight, 2006). Steinmetz et al. (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 compared with 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; Kensinger, Gutchess, & Schacter, 2007). 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 life span.

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 pairs. The number indicated the word's value, ranging from 1 to 12. Critically, the four lowest point values were paired with emotional words, either negatively or positively valenced, between subjects, whereas 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 because of 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 (Charney, 1987; Gick, Craik, & Morris, 1988; Salthouse, 1988). Thus, had half of the items been emotional, and a participant had recalled eight items, recall as a function of being within memory capacity limits would be confounded with recall caused by the word's saliency. For greater capacity younger adults, 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 nonemotional information. The combination of a mixed factorial design 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

Method

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, six men; M age = 21.05, SD = 2.5) were in the negative low-value condition, and 20 (12 women, eight men; M age = 19.75, SD = 1.1) were in the positive low-value condition. A total of 42 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, nine men; M age = 73.79, SD = 6.8) received lists containing negative low-value words, and 21 (12 women, eight 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 American Psychological Association (APA) guidelines and approved by the UCLA or Columbia University Medical School (CUMC) institutional review board (IRB), was obtained prior to study participation.

Materials. The stimuli were four- to 11-letter words. The materials were identical to those used by Castel et al. (2002), except that the four lowest valued words were replaced by either positively (M valence = 8.27, M arousal = 6.35, M dominance = 6.40, M frequency = 21.41; e.g., rainbow) or negatively (M valence = 1.94, M arousal = 5.91, M frequency = 41.31; e.g., murderer) valenced 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 to 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 eight neutral words. Emotional words were paired, at random, with values ranging from 1 to 4, whereas 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 eight 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 s each.

Results

We began by examining the overall performance and selectivity of younger compared with older adults. Because the valence of the emotional words (negative vs. 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, respectively), $F(1, 39) = 15.86$, $p < .001$, $\eta_p^2 = .29$. 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 effects of 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). 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), $F(1, 40) = 1.72$, $p = .20$.

Although the recall results for neutral and positive words fit well with widespread findings of age-related declines in memory, the nonsignificant 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. BF₁₀ 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 of 3 and above provide “positive” to “strong” evidence against H_0 , whereas values between 1 and 3 are “not worth more than a bare mention” ($p = .777$). These results therefore suggest age-related differences in

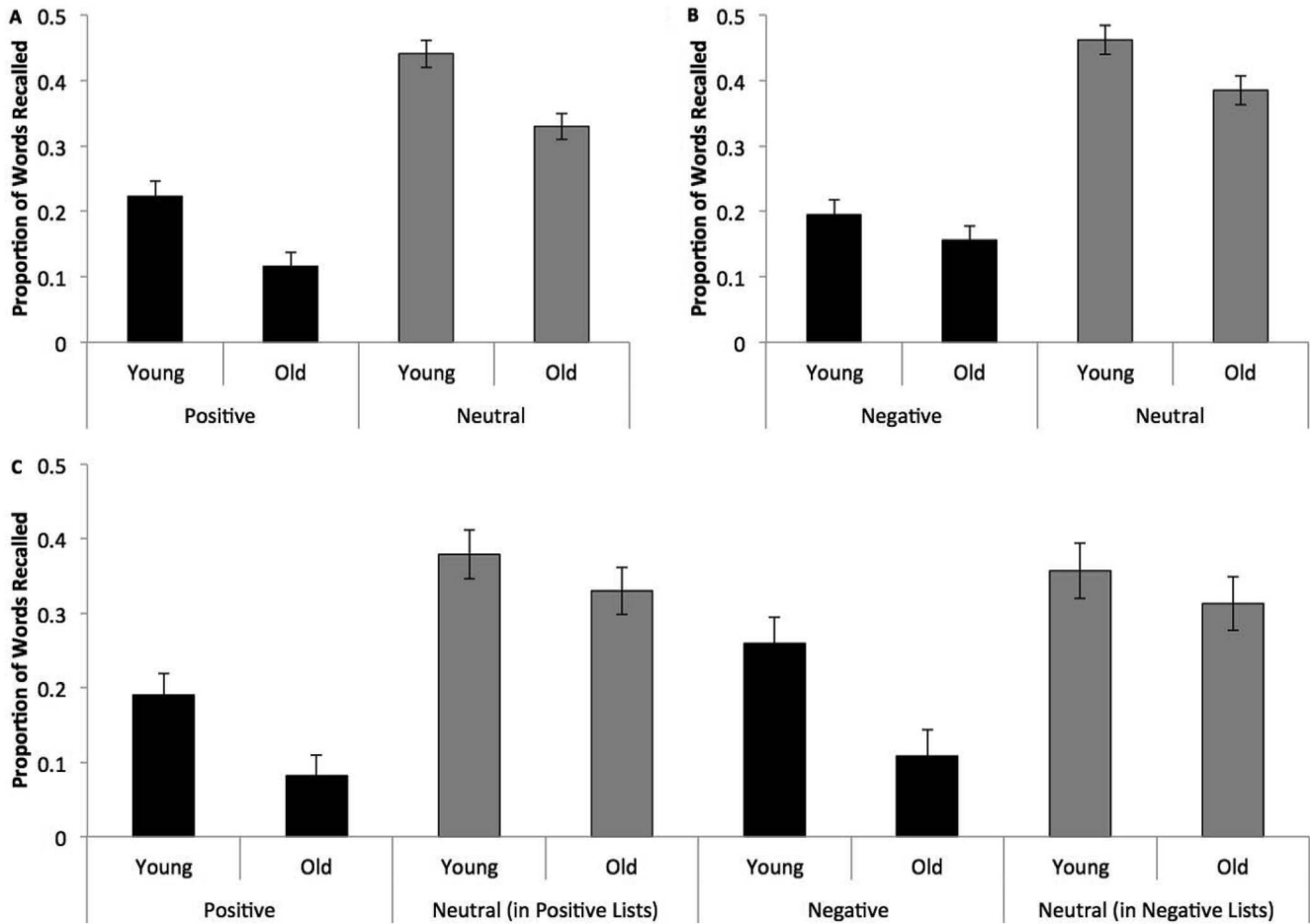


Figure 1. Proportion of recalled words for the younger and older adults. The top panel represents performance for Experiment 1, in which participants were assigned to either the (A) positive low-value condition, in which the words with point values 1 to 4 were positively valenced, and words with values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

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 with 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 in the proportion of negatively valenced words recalled, suggesting that, if anything, older adults demonstrate a negativity bias. Our results also demonstrated that

cognitive control of memory, 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 emotional 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.

Method

Participants. Twenty-one younger adults (15 women, six men; M age = 25, SD = 3.6) and 22 older adults (nine 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 12-letter words. Thirty-two positively valenced words (M valence = 8.31, M arousal = 6.35, M dominance = 6.37, M frequency = 38.06), 32 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 (Bradley & Lang, 1999).

Procedure. Each participant was presented with 16 lists of words (see Appendix B). In each list, four words were emotionally valenced and eight words were neutral. 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, whereas 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 s 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 (M young = 4.89 words, M old = 3.92 words), $F(1, 41) = 17.43$, $p < .000$, $\eta_p^2 = .29$, and thus necessarily had higher scores, as all words were paired with the value "12" (M young = 56.64, M 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 emotional = .40, M 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 \times Age, $F(1, 41) = 1.43$, $p = .24$, Valence \times Age, $F(1, 41) < 1$, Emotion \times Valence, $F(1, 41) = 2.91$, $p = .01$, and Emotion \times Valence \times 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 four lowest point values were paired with negatively and positively valenced words, whereas 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 (M young = 4.58, M old = 3.50), $F(1, 41) = 16.79$, $p < .001$, $\eta_p^2 = .29$. 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 (M young = .46, M old = .56), $F(1, 41) = 1.4$, $p = .24$.

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 \times Age, $F(1, 41) < 1$; Emotion \times Age, $F(1, 41) = 1.8$, $p = .19$; Emotion \times Valence \times 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 valenced, $F(1, 41) = 7.25$, $p = .01$, $\eta_p^2 = .15$, and negatively valenced, $F(1, 41) = 8.78$, $p = .005$, $\eta_p^2 = .18$, words relative to older adults. Paired samples t tests to directly compare the proportion of recall of negatively valenced and 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 was 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 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, whereas 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 with 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 salient 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 & Bäuml, 2006). Although the items in these directed-forgetting paradigms were not emotionally valenced, their 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 condition recalled proportionally more positive and neutral words than did the older adults in this condition. Contrastingly, although younger adults recalled proportionally more neutral words than did older adults in the negative condition, there was no difference in the proportion of negative words recalled for younger and older adults, 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, in which 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 showing that emotional information is better remembered than nonemotional 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 nonemotional information when all other factors are kept constant (Buchanan & Adolphs, 2002). Similarly, many studies have confirmed that emotionally arousing stimuli are processed disproportionately because of 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). Although 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 one third of the words in each list) rather than because of their emotional content. However, even if this was 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' memories 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. This suggests 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 (2006), the positivity bias is most apparent in conditions of full attention, and 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 received lists containing only negative and neutral words, and did not receive positive words. Thus, the nonreplication of the effect in Experiment 2 may be driven by the combination of positive and negative word valences 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, 2016).

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 emo-

tionally 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 attentional control may influence some of these effects of cognitive control over emotional information.

References

- Almeida, D. M. (2005). Resilience and vulnerability to daily stressors assessed via diary methods. *Current Directions in Psychological Science*, *14*, 64–68. <http://dx.doi.org/10.1111/j.0963-7214.2005.00336.x>
- Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General*, *134*, 258–281. <http://dx.doi.org/10.1037/0096-3445.134.2.258>
- Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature*, *411*, 305–309. <http://dx.doi.org/10.1038/35077083>
- Blanchard-Fields, F. (1986). Reasoning on social dilemmas varying in emotional saliency: An adult developmental perspective. *Psychology and Aging*, *1*, 325–333. <http://dx.doi.org/10.1037/0882-7974.1.4.325>
- Bradley, M. M., & Lang, P. J. (1999). *Affective norms for English words (ANEW): Instruction manual and affective ratings* (Technical Report C-1). The Center for Research in Psychophysiology, University of Florida, FL.
- Buchanan, T. W., & Adolphs, R. (2002). The role of the human amygdala in emotional modulation of long-term declarative memory. In S. C. Moore & M. Oaksford (Eds.), *Emotional cognition: From brain to behavior* (pp. 9–34). Amsterdam, the Netherlands: Benjamins. <http://dx.doi.org/10.1075/aicr.44.02buc>
- Castel, A. D. (2008). The adaptive and strategic use of memory by older adults: Evaluative processing and value-directed remembering. In A. S. Benjamin & B. H. Ross (Eds.), *The psychology of learning and motivation* (Vol. 48, pp. 225–270). London, UK: Academic Press.
- Castel, A. D., Benjamin, A. S., Craik, F. I. M., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. *Memory & Cognition*, *30*, 1078–1085. <http://dx.doi.org/10.3758/BF03194325>
- Castel, A. D., McGillivray, S., & Friedman, M. C. (2012). Metamemory and memory efficiency in older adults: Learning about the benefits of priority processing and value-directed remembering. In M. Naveh-Benjamin & N. Ohta (Eds.), *Memory and aging: Current issues and future directions* (pp. 245–270). New York, NY: Psychology Press.
- Charness, N. (1987). Component processes in bridge bidding and novel problem-solving tasks. *Canadian Journal of Psychology*, *41*, 223–243. <http://dx.doi.org/10.1037/h0084151>
- Clark-Foos, A., & Marsh, R. L. (2008). Recognition memory for valenced and arousing materials under conditions of divided attention. *Memory*, *16*, 530–537. <http://dx.doi.org/10.1080/09658210802007493>
- Cowan, N. (2010). The magical mystery four: How is working memory capacity limited, and why? *Current Directions in Psychological Science*, *19*, 51–57. <http://dx.doi.org/10.1177/0963721409359277>
- Denburg, N. L., Buchanan, T. W., Tranel, D., & Adolphs, R. (2003). Evidence for preserved emotional memory in normal older persons. *Emotion*, *3*, 239–253. <http://dx.doi.org/10.1037/1528-3542.3.3.239>
- Depping, M. K., & Freund, A. M. (2013). When choice matters: Task-dependent memory effects in older adulthood. *Psychology and Aging*, *28*, 923–936. <http://dx.doi.org/10.1037/a0034520>
- Gick, M. L., Craik, F. I., & Morris, R. G. (1988). Task complexity and age differences in working memory. *Memory & Cognition*, *16*, 353–361. <http://dx.doi.org/10.3758/BF03197046>
- Grühn, D., Scheibe, S., & Baltes, P. B. (2007). Reduced negativity effect in older adults' memory for emotional pictures: The heterogeneity-homogeneity list paradigm. *Psychology and Aging*, *22*, 644–649. <http://dx.doi.org/10.1037/0882-7974.22.3.644>

- Hahn, S., Carlson, C., Singer, S., & Gronlund, S. D. (2006). Aging and visual search: Automatic and controlled attentional bias to threat faces. *Acta Psychologica*, *123*, 312–336. <http://dx.doi.org/10.1016/j.actpsy.2006.01.008>
- Hasher, L., & Zacks, R. T. (2006). Aging and long term memory: Deficits are not inevitable. In E. Bialystok & F. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 162–177). New York, NY: Oxford University Press.
- Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology*, *75*, 887–900. <http://dx.doi.org/10.1037/0022-3514.75.4.887>
- Kass, R., & Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association*, *90*, 773–795. <http://dx.doi.org/10.1080/01621459.1995.10476572>
- Kensinger, E. A. (2009). Remembering the details: Effects of emotion. *Emotion Review*, *1*, 99–113. <http://dx.doi.org/10.1177/1754073908100432>
- Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2006). Memory for specific visual details can be enhanced by negative arousing content. *Journal of Memory and Language*, *54*, 99–112. <http://dx.doi.org/10.1016/j.jml.2005.05.005>
- Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2007a). Effects of emotion on memory specificity in young and older adults. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences*, *62*, P208–P215. <http://dx.doi.org/10.1093/geronb/62.4.P208>
- Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2007b). How negative emotion enhances the visual specificity of a memory. *Journal of Cognitive Neuroscience*, *19*, 1872–1887. <http://dx.doi.org/10.1162/jocn.2007.19.11.1872>
- Kensinger, E. A., Gutchess, A. H., & Schacter, D. L. (2007). Effects of aging and encoding instructions on emotion-induced memory trade-offs. *Psychology and Aging*, *22*, 781–795. <http://dx.doi.org/10.1037/0882-7974.22.4.781>
- Kester, J. D., Benjamin, A. S., Castel, A. D., & Craik, F. I. M. (2002). Memory in the elderly people. In A. D. Baddeley, B. A. Wilson, & M. Kopelman (Eds.), *Handbook of memory disorders* (2nd ed., pp. 543–568). London, UK: Wiley.
- Kisley, M. A., Wood, S., & Burrows, C. L. (2007). Looking at the sunny side of life: Age-related change in an event-related potential measure of the negativity bias. *Psychological Science*, *18*, 838–843. <http://dx.doi.org/10.1111/j.1467-9280.2007.01988.x>
- Leclerc, C. M., & Kensinger, E. A. (2008). Effects of age on detection of emotional information. *Psychology and Aging*, *23*, 209–215. <http://dx.doi.org/10.1037/0882-7974.23.1.209>
- LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life*. New York, NY: Simon & Schuster.
- LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, *23*, 155–184. <http://dx.doi.org/10.1146/annurev.neuro.23.1.155>
- Leshikar, E. D., Dulas, M. R., & Duarte, A. (2015). Self-referencing enhances recollection in both young and older adults. *Aging, Neuropsychology, and Cognition*, *22*, 388–412. <http://dx.doi.org/10.1080/13825585.2014.957150>
- Lichtenstein, P., Gatz, M., & Berg, S. (1998). A twin study of mortality after spousal bereavement. *Psychological Medicine*, *28*, 635–643. <http://dx.doi.org/10.1017/S0033291798006692>
- Love, J., Selker, R., Verhagen, J., Marsman, M., Gronau, Q. F., Jamil, T., . . . Wagenmakers, E. J. (2015). JASP (Version 0.6) [Computer software]. Retrieved from <http://jasp.ism.ac.jp/index-e.html>
- Mather, M. (2007). Emotional arousal and memory binding: An object-based framework. *Perspectives on Psychological Science*, *2*, 33–52. <http://dx.doi.org/10.1111/j.1745-6916.2007.00028.x>
- Mather, M., & Carstensen, L. L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in Cognitive Sciences*, *9*, 496–502. <http://dx.doi.org/10.1016/j.tics.2005.08.005>
- Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly: Threat detection is not impaired among older adults. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences*, *61*, P54–P57. <http://dx.doi.org/10.1093/geronb/61.1.P54>
- Mikels, J. A., & Shuster, M. M. (2016). The interpretative lenses of older adults are not rose-colored—just less dark: Aging and the interpretation of ambiguous scenarios. *Emotion*, *16*, 94–100. <http://dx.doi.org/10.1037/emo0000104>
- Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*, 81–97. <http://dx.doi.org/10.1037/h0043158>
- Murphy, N. A., & Isaacowitz, D. M. (2008). Preferences for emotional information in older and younger adults: A meta-analysis of memory and attention tasks. *Psychology and Aging*, *23*, 263–286. <http://dx.doi.org/10.1037/0882-7974.23.2.263>
- Reisberg, D., & Heuer, F. (2004). Remembering emotional events. In D. Reisberg & P. Hertel (Eds.), *Memory and emotion* (pp. 1–41). New York, NY: Oxford University Press. <http://dx.doi.org/10.1093/acprof:oso/9780195158564.003.0001>
- Salthouse, T. A. (1988). Initiating the formalization of theories of cognitive aging. *Psychology and Aging*, *3*, 3–16. <http://dx.doi.org/10.1037/0882-7974.3.1.3>
- Seigo, S. A., Golding, J. M., & Gottlob, L. R. (2006). Directed forgetting in older adults using the item and list methods. *Aging, Neuropsychology, and Cognition*, *13*, 95–114. <http://dx.doi.org/10.1080/138255890968682>
- Steinmetz, K. R. M., Muscatell, K. A., & Kensinger, E. A. (2010). The effect of valence on young and older adults' attention in a rapid serial visual presentation task. *Psychology and Aging*, *25*, 239–245. <http://dx.doi.org/10.1037/a0018297>
- Thorndike, E., & Lorge, I. (1944). *The teacher's word book of 30,000 words*. New York, NY: Bureau of Publications, Teacher's College, Columbia University.
- Vuilleumier, P., & Driver, J. (2007). Modulation of visual processing by attention and emotion: Windows on causal interactions between human brain regions. *Philosophical Transactions of the Royal Society of London: Series B: Biological Sciences*, *362*, 837–855.
- Watkins, M. J., & Bloom, L. C. (1999). *Selectivity in memory: An exploration of willful control over the remembering process*. Unpublished manuscript, Department of Psychology, Rice University, Houston, TX.
- Wood, S., & Kisley, M. A. (2006). The negativity bias is eliminated in older adults: Age-related reduction in event-related brain potentials associated with evaluative categorization. *Psychology and Aging*, *21*, 815–820. <http://dx.doi.org/10.1037/0882-7974.21.4.815>
- Zellner, M., & Bäuml, K. H. (2006). Inhibitory deficits in older adults: List-method directed forgetting revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 290–300. <http://dx.doi.org/10.1037/0278-7393.32.3.290>

Appendix A
Word-Value Pairs by List for Experiment 1

List 1	List 2	List 3	List 4
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
List 5	List 6	List 7	List 8
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

Note. Participants received either negatively- or positively-valenced words. Neutral words were the same across conditions.

(Appendices continue)

Appendix B
Word-Value Pairs by List for Experiment 2

List 1		List 2		List 3		List 4	
utensil	6	success	2	part	12	umbrella	12
disaster	4	bowl	11	spray	12	murderer	12
concentrate	12	windmill	5	terrorist	12	jail	12
rabies	1	treasure	3	manner	12	fork	12
paper	11	material	12	pig	12	cabinet	12
golfer	8	rough	8	time	12	misery	12
army	5	avenue	9	nightmare	12	name	12
cork	10	rattle	6	arm	12	suicide	12
chair	9	victory	1	body	12	door	12
iron	7	ankle	10	tragedy	12	machine	12
suffocate	2	bathroom	7	hammer	12	fabric	12
terrible	3	champion	4	killer	12	column	12
List 5		List 6		List 7		List 8	
seat	8	writer	9	news	12	jug	12
storm	11	win	3	table	12	laughter	12
boxer	7	ship	6	thermometer	12	doctor	12
rejected	4	item	7	rainbow	12	chin	12
clock	12	finger	8	pencil	12	triumphant	12
cruel	2	paradise	4	cannon	12	lamp	12
tank	5	noisy	11	joyful	12	serious	12
toothache	1	square	12	nun	12	hairdryer	12
tease	9	miracle	2	happy	12	baby	12
infection	3	passage	10	comedy	12	office	12
lawn	10	cash	1	odd	12	vest	12
metal	6	cord	5	sphere	12	proud	12
List 9		List 10		List 11		List 12	
elevator	11	locker	12	joy	12	elbow	12
poison	4	ulcer	12	month	12	black	12
ink	8	violin	12	stomach	12	headlight	12
slave	2	hard	12	foot	12	lucky	12
mantel	5	hatred	12	valentine	12	curtains	12
engine	10	theory	12	museum	12	kiss	12
tower	12	history	12	glass	12	paint	12
icebox	6	appliance	12	vacation	12	jelly	12
street	7	hospital	12	love	12	thrill	12
drown	3	rape	12	dark	12	board	12
truck	9	disloyal	12	banner	12	pleasure	12
betray	1	hay	12	egg	12	lantern	12
List 13		List 14		List 15		List 16	
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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