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Evidence for Preserved Emotional Memory in Normal Older Persons

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Emotion has been shown to have a modulatory effect on declarative memory. Normal aging is associated with a decline in declarative memory, but whether aging might affect the influence of emotion on memory has not been established. To investigate this, we administered a task that provides a detailed assessment of emotional memory to 80 neurologically normal adults ranging in age from 35 to 85 years. Across ages, memory performance was found to be modulated by the emotional significance of stimuli in a comparable manner (improved memory for gist, compromised memory for visual detail), despite an overall decline in memory performance with increasing age. The results raise the interesting possibility that aging has a differential effect on hippocampal versus amygdala function.

A growing body of research in normal participants has established that emotionally arousing stimuli and events are more memorable than neutral ones (Bradley, Greenwald, Petry, & Lang, 1992; Burke, Heuer, & Reisberg, 1992). In fact, this “booster effect” of emotion on memory is quite robust, although there are a number of complexities in this literature that have yet to be resolved (Heuer & Reisberg, 1990). For example, one important specification is that memory for *gist* tends to be enhanced by emotional arousal, whereas memory for *visual detail* tends to be suppressed (Adolphs, Buchanan, & Tranel, 2002; Adolphs, Denburg, & Tranel, 2001; Burke et al., 1992; Reisberg & Heuer, 1992; Wessel & Merckelbach, 1998). Although many questions have yet to be answered, the general idea is that there is a sort of trade-off effect, whereby memory for gist is enhanced at the expense of memory for visual detail (Adolphs et al., 2002).

In a related context, a specific role for emotional arousal in enhancing the memorability of an event has been suggested both by studies that have manipulated the arousing nature of a stimulus by the context in which it occurs (Cahill & McGaugh, 1995) and by pharmacological manipulation of beta adrenergic and glucocorticoid systems (Buchanan & Lovallo, 2001; Cahill, Prins, Weber, & McGaugh, 1994). It appears that emotional arousal operates at the level of encoding and consolidation of material into long-term declarative memory, rather than directly on subsequent retrieval mechanisms (Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Hamann, Ely, Grafton, & Kilts, 1999). The effects of emotional arousal on memory appear to persist for some time (e.g., months or even years), plausibly modulating consolidation and affecting the structure of memory traces.

One factor that has received minimal attention in this literature is age, and this is the focus of the present study. It is well-known that the ability to acquire declarative information declines with age, especially after the sixth decade (Horn, 1982; Lezak, 1995; Schaie, 1996). Moreover, there are plausible neural correlates for this age-related change, inasmuch as studies have shown downward changes in cellular,

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morphologic, and volumetric aspects of the hippocampus and related mesial temporal structures as a function of aging (e.g., Golomb et al., 1993; Jernigan et al., 2001; Morrison & Hof, 2002; Schuff et al., 1999). By contrast, whether there are systematic age-related changes in emotional function is less well established, and the specific question of whether the modulatory effects of emotion on memory are affected by aging has scarcely been studied. Virtually all of the extant studies regarding the effects of emotion on memory have been conducted with young participants (Bradley et al., 1992; Burke et al., 1992; Cahill et al., 2001; Cahill & McGaugh, 1995; Christianson & Loftus, 1991; Hamann, Ely, et al., 1999; Heuer & Reisberg, 1990), or in pathological conditions (Hamann, Cahill, & Squire, 1997; Hamann, Monarch, & Goldstein, 1999; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). (There have been several studies of how aging influences the phenomenon of "flashbulb" memory [e.g., G. Cohen, Conway, & Maylor, 1994; Tekcan & Peynircioğlu, 2002]. However, we are reluctant to draw direct comparisons between these studies and the emotional memory literature cited above because flashbulb memories appear to represent a phenomenon that is categorically different from what is normally studied under the rubric of emotional memory. Because this applies to the study we report here as well, we have opted not to address the flashbulb memory literature, even though we recognize that a more complete synthesis of these different lines of investigation may eventually be possible.)

Our objective in the present study was to investigate the influence of aging on the modulatory effects of emotion on memory. To do this, we studied young, middle-aged and older participants with a standard emotional memory paradigm that measured participants' ability to acquire and retain information that was neutral, positively valenced, or negatively valenced. The key effect we were interested in exploring was whether emotion (positive or negative valence) would influence memory to a comparable degree in the different age groups. In accordance with the literature, we expected an overall decline in memory with age. There is insufficient evidence, though, to make a strong prediction regarding emotion, and we considered the following two outcomes possible: (a) that emotion would influence memory to a comparable extent across age groups, in which case age and emotion (valence) should not interact; or (b) that aging would alter the effects of emotion on memory, in which case age and emotion (valence) would interact.

Method

Participants

Three age groups were included. (We chose to create age groups, rather than use age as a continuous variable, because this allowed better congruence between the experimental measures and the background neuropsychological data. Also, operationalizing the independent variable of age in this fashion is a common strategy in the literature.) The sample sizes, gender ratio, and level of education were approximately equal in the three groups (see Table 1). The age breakdown was as follows: young ($n = 26$; aged 35–51); middle-aged ($n = 27$; aged 52–69); and older ($n = 27$; aged 70–85). Because of its potential importance, gender was included as a factor in all of the analyses, although there were no a priori predictions regarding gender effects. Participants were financially compensated for their participation. A structured interview screening procedure was used to determine that all persons enrolled in the study were neurologically healthy, using a method described previously (Tranel, Benton, & Olson, 1997).

There were no differences between young, middle-aged and older groups on measures of visual perception (Benton Facial Recognition Test; Benton, Sivan, Hamsher, Varney, & Spreen, 1994), $F(2, 79) = 0.28$, $p > .05$; emotional recognition (Ekman faces; Ekman & Friesen, 1975), $F(2, 64) = 2.05$, $p > .05$; reading ability (Wide Range Achievement Test—Third Edition Reading Test; Jastak & Wilkinson, 1993), $F(2, 79) = 1.34$, $p > .05$; mental status (Mini-Mental State Exam; Folstein, Folstein, & McHugh, 1975), $F(2, 79) = 1.74$, $p > .05$; attention (Wechsler Adult Intelligence Scale–Third Edition Digit Span; Wechsler, 1997) $F(2, 79) = 0.30$, $p > .05$; or level of affective symptomatology (Beck Depression Inventory; Beck, 1987), $F(2, 79) = 0.22$, $p > .05$. These measures suggest that the participants did not differ significantly on variables that may impact memory acquisition and retention. Demographic and cognitive characteristics of the sample are provided in Table 1.

Researchers have suggested that the booster effects of emotion on memory may be reduced in persons who are administered beta-adrenergic receptor antagonists (Cahill et al., 1994). Given this, and given the high base rates of antihypertensive use among older persons, participants' medication histories were carefully reviewed, and those prescribed a beta-adrenergic receptor antagonist (e.g., propranolol hydrochloride) at the time of our study ($n = 11$) were removed and the data reanalyzed. The findings for all

Table 1
Demographic and Cognitive Characteristics of the Sample

	Participant group			Post hoc comparison		
Characteristic	Y (n = 26)	M (n = 27)	O (n = 27)	Y vs. M	Y vs. O	M vs. O
Age						
M	43.23	60.48	76.41	—	—	—
SD	5.40	5.52	4.78			
% Females	46%	52%	52%	—	—	—
Education						
M	15.08	15.67	15.81	*ns*	*ns*	*ns*
SD	2.00	2.87	2.86			
% Right-handed	81%	85%	96%	—	—	—
BDI						
M	4.15	4.78	4.63	*ns*	*ns*	*ns*
SD	3.16	3.53	4.05			
Ekman faces						
M	33.48	33.08	31.67	*ns*	*ns*	*ns*
SD	2.97	2.73	3.18			
WAIS–III Digit Span						
M	17.69	16.89	17.52	*ns*	*ns*	*ns*
SD	3.89	4.76	3.07			
Benton faces						
M	22.54	22.15	22.30	*ns*	*ns*	*ns*
SD	2.18	1.97	1.49			
WRAT–3 Reading						
M	49.54	49.52	51.04	*ns*	*ns*	*ns*
SD	4.10	3.54	4.04			
RAVLT 30-min delay						
M	11.50	10.15	8.67	*ns*	$p < .01$	*ns*
SD	2.90	2.48	2.83			
BVRT no. errors						
M	2.88	3.26	4.63	*ns*	$p < .05$	*ns*
SD	2.25	2.09	2.37			
WMS–III faces delay						
M	37.88	38.19	35.74	*ns*	$p < .05$	$p < .05$
SD	4.15	3.29	3.94			
Verbal fluency						
M	42.12	44.04	40.00	*ns*	*ns*	*ns*
SD	10.00	11.06	8.32			
Trailmaking Test—Form B						
M	53.54	60.67	86.26	*ns*	$p < .01$	*ns*
SD	13.31	20.41	26.71			
WCST no. categories						
M	5.91	5.96	5.74	*ns*	*ns*	*ns*
SD	0.43	0.21	1.05			
WCST persev. errors						
M	6.73	7.26	10.83	*ns*	*ns*	*ns*
SD	3.10	3.19	9.38			

Note. Post hoc comparisons were computed with independent-samples *t* tests. Raw scores are provided for each of the neuropsychological variables. Y = young; M = middle-aged; O = older; BDI = Beck Depression Inventory; WAIS–III Digit Span = Wechsler Adult Intelligence Scale—Third Edition Digit Span; WRAT–3 Reading = Wide Range Achievement Test—Revision 3 Reading subset; RAVLT 30-min delay = Rey Auditory Verbal Learning Test 30-minute delayed recall; BVRT no. errors = Benton Visual Retention Test number of errors; WMS–III faces delay = Wechsler Memory Scale—Third Edition faces delayed memory; WCST no. categories = Wisconsin Card Sorting Test number of categories achieved; WCST persev. errors = Wisconsin Card Sorting Test number of perseverative errors committed.

measures were unchanged with the exclusion of these participants, and accordingly, results are reported for the entire sample. (We should add that the absence of an effect here was not surprising, given that this factor was not manipulated systematically and given that we had small sample sizes to address this effect.)

Stimuli

The emotional memory experiment was administered to all participants in conjunction with a comprehensive battery of neuropsychological tests. The stimuli for the experiment consisted of 15 pictures of social situations (5 neutral: e.g., students listening to a guest lecturer; 5 negative: e.g., a mutilated body, and 5 positive: e.g., parents with their new twin babies). All stimuli were color digital images of approximately equal visual complexity (as determined by the experimenters). The stimuli were presented in blocks of valence type, and the order of presentation of the blocks was counterbalanced across participants. Several of the stimuli were chosen from the International Affective Picture System (Center for the Study of Emotion and Attention, 1999), and the rest were drawn from print media sources. The task has been used previously in brain-damaged participants with unilateral (Buchanan, Denburg, Tranel, & Adolphs, 2001) or bilateral (Adolphs et al., 2001) amygdala damage.

Procedure

Participants were tested individually on two consecutive days. Each testing session lasted 1 hr 30 min (each session included various neuropsychological tests and the experimental task). On Day 1, participants were seated in a darkened room approximately 30 cm in front of a large color computer monitor. Each visual stimulus was displayed for 20 s and was accompanied by a simple one-sentence narrative description read by the examiner. (The same examiner tested all the participants and read the narratives in the same way to all the participants. We did not use a tape recorder because some participants—especially older ones—find this interpersonally off-putting and contrived.) For example, the narrative description for a photograph of a starving child was as follows: “This child in Somalia received intravenous feeding, but died a few days later.” Each narrative sentence contained information that could not be gleaned from the visual stimulus alone. Participants were told to pay close attention to the stimuli and the narrative and to try to “feel” the emotion that was being expressed. Participants were not told that this was a test of memory. Following a 24-hr delay, participants’ memory for the stimuli was assessed in several ways (see below): (a) a task that measured memory for gist (free recall), (b) a task that measured memory for visual detail (four-alternative forced-choice recognition), and (c) a task that combined aspects of both gist and visual detail memory (cued recall). During a debriefing session at the end of the second visit, all participants indicated that they were unaware that their memory would be tested. Finally, a subset of the original participants completed long-term follow-up evaluations in an effort to assess the stability of the memory effects over an extended retention interval. This long-term follow-up was also “incidental” in the sense that participants were not warned that their memory would be assessed.

Memory Tests: 24-hr Delay

1. Free recall: Approximately 24 hr following exposure, participants were asked to freely recall as many of the stimuli as possible. They were told to take as much time as they wished and to continue until they felt they could recall no more. Participants were asked to write down all remembered information regarding the visual stimuli and the narrative sentences. Free-recall responses were scored by two independent scorers who were blind to the participant’s age and to the objectives of this study. A recall was scored as correct if the participant’s description of a specific picture or narrative could be clearly linked by both scorers to a picture that had been shown. Most of the responses given in the free-recall test could be clearly linked to a particular picture or narrative. There was a high degree of agreement between the two scorers ($\kappa = .90$; J. Cohen, 1960). Recall descriptions that could not be clearly linked to a particular picture by both scorers were scored as incorrect. Given our scoring method, this task assessed recall memory for gist.

2. Cued recall: Immediately after the free-recall test, participants were administered a cued-recall test containing six written multiple-choice questions for each of the 15 slides presented to the participant, for a total of 90 multiple-choice questions. Questions concerned a broad range of information about the stimuli, encompassing memory for both gist and visual detail.

3. Four-alternative forced-choice recognition: Immediately after the cued-recall test, participants

were administered a visual four-alternative forced-choice memory test. For each of the stimuli, the original scene was shown, along with three foils that contained computer-altered details of the original picture (e.g., the number of babies depicted; the type of surface the mutilated body was lying on). Participants were instructed to identify the image that was identical to the stimulus that they viewed the previous day. Given the construction of the stimuli and the demands of the test, this task assessed memory for visual detail.

Memory Tests: Long-Term Follow-Up

Approximately 8 months following the initial testing, a subset of the participants were examined. Forty-three participants (9 young, 22 middle-aged, 12 older) returned to the laboratory for this follow-up assessment (mean ± standard error of the delay interval: 7.9 ± 0.27 months; range = 5–11 months). Participants were not told that their memory would be tested; rather, they were led to believe that they were returning to the laboratory for a new experiment. There were no group differences in the interval between initial testing and follow-up testing, $F(2, 34) < 1$, and the length of the delay interval was not associated with memory performance (rs < .21, ps > .05). At follow-up, participants completed the same free- and cued-recall tests as before in addition to a new yes–no recognition test (the latter was used because of the likelihood of floor effects on our original Four Forced-Choice Alternative Recognition Test). The yes–no recognition test consisted of a randomized combination of the 15 original stimuli and 15 distractor stimuli of comparable valence categories. Participants were simply asked to indicate which of the images they had viewed previously. Follow-up data were analyzed in the same manner as those from the 24-hr testing.

Emotion Manipulation Check

To explore potential age effects on memory and emotion, it is critical that the present experiment not be confounded by basic age-related differences in the manner in which participants perceived and experienced the emotional valence of the stimuli. That is, different age cohorts should have had comparable emotional experiences of the different types of stimuli. To check this, a psychophysiological index sensitive to emotional arousal (skin conductance) and two rating scales were used.

Skin conductance. Skin conductance was recorded from two silver silver-chloride electrodes attached to the thenar and hypothenar eminences of the left hand. Before the experiment, participants were administered several basic orienting stimuli (e.g., deep breath, loud noise), and for the analyses of skin conductance, participants who failed to produce skin conductance responses (SCRs) to such orienting stimuli ($n = 13$; see below) were removed. For the experiment proper, the peak amplitude of SCRs that occurred was measured within 1–4 s following stimulus onset, using standard procedures (Tranel, Fowles, & Damasio, 1985). Skin conductance was recorded during the first exposure to the stimuli, that is, on Day 1.

Rating scales. A subset of the participants ($n = 37$; 12 young, 12 middle-aged, 13 older) were asked to rate each of the pictures on 9-point Likert scales of pleasantness (1 = *unpleasant*; 5 = *neutral*; 9 = *pleasant*) and arousal (1 = *low arousal*; 5 = *neutral*; 9 = *high arousal*). Specifically, upon completion of the memory tests at the second session, these participants were shown the original stimuli again and asked to complete the pleasantness and arousal ratings. These dimensions were chosen for ratings because these two aspects of emotion create a reliable two-dimensional plot, referred to as a *circumplex model* (Barrett, 1998). (The participants who completed the rating scales had one additional exposure to the stimuli during this procedure. Most of these participants were also involved in the long-term follow-up testing; however, we analyzed the long-term follow-up data both with and without the participants who had completed the rating scales, and there were no differences in the outcomes. It is also important to note that approximately equal numbers of participants in each of the three age groups were involved in the extra-exposure and follow-up testing, so this factor did not vary systematically as a function of age.)

Data Analysis

Each dependent variable (memory performances, pleasantness and arousal ratings, and SCRs) was subjected to separate 3 (age group; young, middle-aged, older) × 2 (gender) × 3 (valence: neutral, positive, negative) multivariate analyses of variance (MANOVAs), with age and gender as between-subjects factors and valence as a within-subjects factor. For all mixed-model analyses, the multivariate approach was used to control for violations of the sphericity assumption (Maxwell & Delaney, 1990; Vasey & Thayer, 1987). Wilks's lambda (λ), the associated degrees of freedom, and a measure of effect size (eta squared; η^2) are reported for each MANOVA. Follow-up contrasts involving three or more comparisons were corrected by using the Bonferroni approach; all other analyses used $p = .05$ as the critical value.

Results

Picture Ratings

Figure 1 shows the mean pleasantness ratings as a function of a priori valence classification based on previous reports in which these stimuli have been used (Adolphs, Tranel, & Denburg, 2000; Buchanan et al., 2001; Lang, Bradley, & Cuthbert, 1995). The age groups did not differ on pleasantness ratings, $F(2, 31) = 1.3$, $p > .2$, $\eta^2 = 0.08$; nor was there an Age × Valence interaction ($\lambda = 0.85$), $F(4, 60) = 1.3$, $p > .2$, $\eta^2 = 0.08$. Results illustrate the expected effect of valence, with the positive pictures rated as more pleasant than both the neutral and negative pictures ($\lambda = 0.01$), $F(2, 30) = 11.89$, $p < .0001$, $\eta^2 = 0.99$. Although there was not a significant main effect of gender ($F < 1$), there was a significant Gender × Valence interaction ($\lambda = 0.8$), $F(2, 30) = 3.8$, $p < .05$, $\eta^2 = 0.2$ (data not shown). Follow-up contrasts illustrated that women rated the negative pictures as slightly more unpleasant than men ($p < .05$; women, $M = 1.23$; men, $M = 1.60$). These findings indicate that age of participant did not affect pleasantness ratings.

Ratings of arousal are shown in Figure 2. There was no significant age group difference in arousal ratings, $F(2, 31) = 1.9$, $p < .1$, $\eta^2 = 0.11$. The Age × Valence interaction was also nonsignificant ($\lambda = 0.93$), $F(2, 30) < 1$, $p > .7$, $\eta^2 = 0.04$. There was a main effect of valence ($\lambda = 0.16$), $F(2, 30) = 77.5$, $p < .0001$, $\eta^2 = 0.84$. Contrasts illustrated that negative stimuli were rated as more arousing than both positive and neutral stimuli (*p*s < .0001), and the positive stimuli were more arousing than the neutral stimuli ($p < .0001$). Women rated the slides as more arousing overall than did men, $F(1, 31) = 8.3$, $p < .01$, $\eta^2 = 0.21$ (women, $M = 5.93$; men, $M = 5.15$). The effects of gender on arousal ratings were not, however, specific to any valence category, as indicated by a nonsignificant Gender × Valence interaction ($\lambda = 0.26$), $F(4, 60) < 1$, $p > .6$, $\eta^2 = 0.02$. These data both validate the a priori stimulus categories we used and illustrate that the age groups showed the same pattern of arousal ratings in response to these stimulus categories.

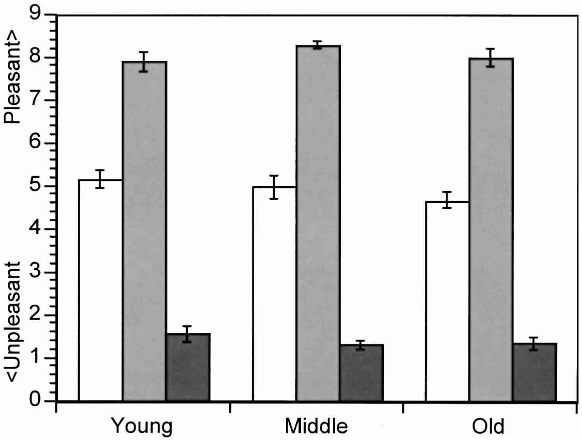

Figure 1. Mean (± standard error) ratings of valence are shown for the neutral (open bars), positive (gray bars), and negative (solid bars) stimuli. The scale represents maximum pleasantness at 9, maximum unpleasantness at 1, and neutral pleasantness at 5. Data are presented by age group.

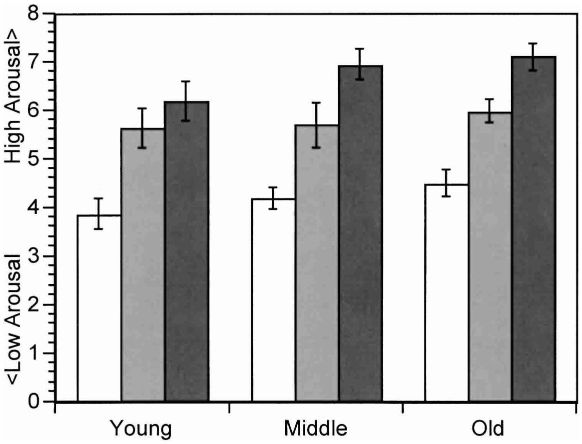

Figure 2. Mean (± standard error) ratings of arousal are shown for the neutral (open bars), positive (gray bars), and negative (solid bars) stimuli. The scale represents maximum arousal at 9, minimum arousal at 1, and neutral arousal at 5. Data are presented by age group.

SCRs

Figure 3 shows the mean SCRs across valence categories for the three age groups. We discarded data from 13 participants (4 young men, 3 young women, 5 older men, and 1 older woman) because of a lack of measurable SCRs to orienting stimuli (this base rate of electrodermal unresponsiveness is generally consistent with the reported occurrence in normal populations; e.g., Bernstein et al., 1982).

SCRs did not differ significantly between the

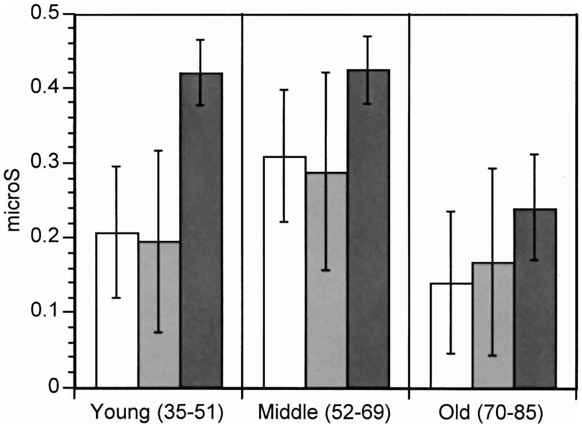

Figure 3. Mean (± standard error) skin conductance responses in microsiemens (microS) as measured during the initial viewing of the stimuli are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli.

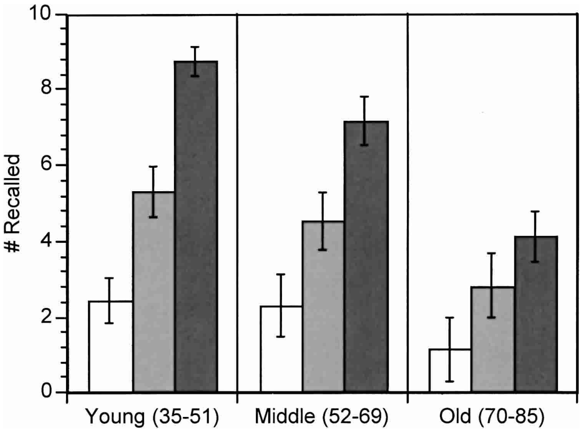

Figure 4. Memory performance on the 24-hr free-recall task. Mean (± standard error) number of slides correctly recalled are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli; pound sign = number.

young, middle-aged and older groups, $F(2, 61) < 1$, $p > .3$, $\eta^2 = 0.03$, even though the older group displayed lower SCRs than the young and middle-aged groups. There was a significant effect of valence ($\lambda = 0.8$), $F(2, 60) = 7.5$, $p < .05$, $\eta^2 = 0.2$, but no Age × Valence interaction ($\lambda = 0.95$), $F(4, 120) < 1$, $p > .5$, $\eta^2 = 0.03$. Follow-up contrasts revealed increased SCRs to the negative stimuli compared with both the neutral and the positive stimuli (ps $< .002$). Because of the relatively large variance of responses, none of the individual group comparisons within valence categories reached significance. There were no differences in SCRs between men and women ($F < 1$). These data indicate that young, middle-aged and older age groups show broadly similar patterns of SCRs to emotionally valent stimuli, in a manner typical for stimuli of this type (Bradley et al., 1992; Lang, Greenwald, Bradley, & Hamm, 1993).

Memory Performances

24-hr free recall. Figure 4 shows the 24-hr free-recall performance for the three age groups, as a function of valence category. The patterns of recall across the stimulus categories were not found to be significantly different among the age groups (Age × Valence interaction: $\lambda = 0.89$), $F(4, 146) = 2.1$, $p = .08$, $\eta^2 = 0.05$. As predicted, there was a main effect of age group, $F(2, 74) = 7.4$, $p < .05$, $\eta^2 = 0.17$. Follow-up contrasts revealed that the older group recalled significantly fewer stimuli than did both the young ($p = .001$) and middle-aged ($p = .02$) groups. The young and middle-aged groups did not differ in their free-recall performance ($p > .7$). Additionally, there was a significant main effect of valence ($\lambda = 0.42$), $F(2, 73) = 50.2$, $p < .0001$, $\eta^2 = 0.58$. The negative stimuli were remembered significantly better than both the positive and the neutral stimuli (ps $< .0001$), and the positive stimuli were remembered significantly better than the neutral stimuli ($p < .0001$). Finally, women showed slightly better free-recall performance than the men, but this difference was not statistically significant, $F(1, 74) = 2.8$, $p = .1$ (women, $M = 4.80$; men, $M = 3.80$).

24-Hr Cued Recall

As depicted in Figure 5, there was not a significant Age × Valence interaction (Fs < 1). However, individual contrasts illustrated that the young group remembered both neutral and negative stimuli significantly better than the older group (ps $< .006$), and the middle-aged group remembered significantly more negative stimuli than the older group ($p = .03$). A significant effect of valence was also unsupported. Similar to the free-recall performance, there was a significant effect of age group, $F(2, 74) = 8.1$, $p < .05$, $\eta^2 = 0.18$; with the young group performing better than both the older ($p < .0001$) and the middle-aged groups ($p < .05$), whereas the difference between older and middle-aged groups did not reach significance ($p = .31$). Women performed significantly better than did men on the cued-recall questions, $F(1, 74)$

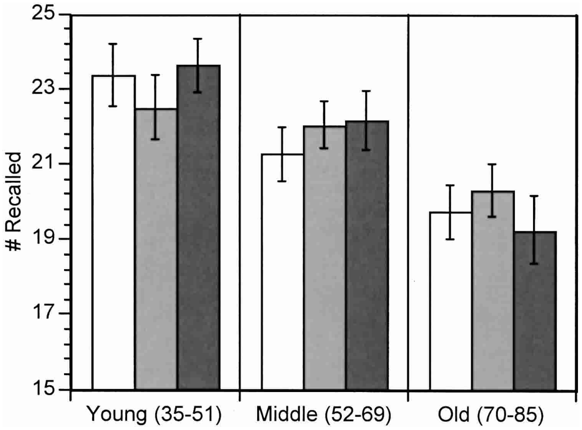

Figure 5. Memory performance on the 24-hr cued-recall task. Mean (± standard error) number of correct responses are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli; pound sign = number.

= 7.3, $p < .01$, $\eta^2 = 0.09$ (women, $M = 22.50$; men, $M = 20.70$).

24-Hr Four-Alternative Forced-Choice Recognition

As shown in Figure 6, there was no significant difference in the pattern of recognition among the age groups (Age × Valence interaction: $\lambda = 0.24$), $F(4, 146) < 1$, $\eta^2 = 0.006$. As in the free-recall and cued-recall tests, there was a significant main effect of age group, $F(2, 74) = 6.0$, $p < .005$, $\eta^2 = 0.14$. The older group showed significantly lower performance compared with the young group ($p < .01$), but there were no other significant between-group differences (ps > .18). There was also a significant effect of valence, with the opposite pattern as in free recall: neutral > positive > negative ($\lambda = 0.63$), $F(2, 73) = 21.5$, $p < .0001$, $\eta^2 = 0.37$. Contrasts illustrated that the neutral stimuli were recognized better than both the positive ($p < .05$) and negative stimuli ($p < .0001$), and the positive stimuli were recognized better than the negative stimuli ($p < .0001$). Individual contrasts, however, illustrated that the young group recognized both the positive ($p = .015$) and negative pictures ($p = .01$) better than the older group. The middle-aged group did not differ from the other two groups. Men and women did not differ in recognition performance, $F(1, 74) < 1$.

Long-Term Follow-Up

Free recall. The pattern of results for free recall at long-term follow-up was similar to that observed at 24 hr, save for an overall decrease in performance (see Figure 7). There was no significant Age × Valence interaction ($\lambda = 0.53$, Fs < 2.1, ps > .1, $\eta^2 = 0.03$). There was a significant main effect of age group, $F(2, 37) = 6.0$, $p < .01$, $\eta^2 = 0.25$; with the young group recalling significantly more stimuli than

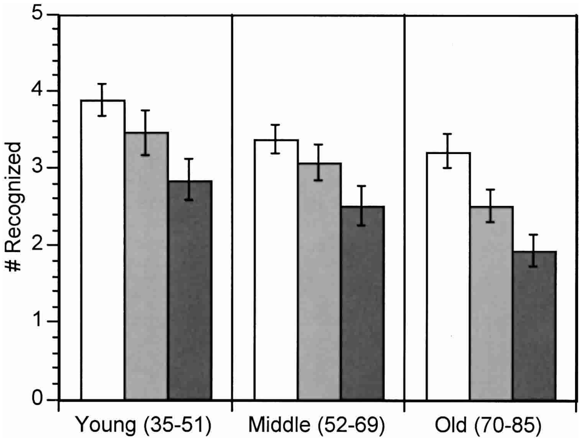

Figure 6. Memory performance on the 24-hr four-alternative forced-choice recognition task. Mean (± standard error) number of correct responses are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli; pound sign = number.

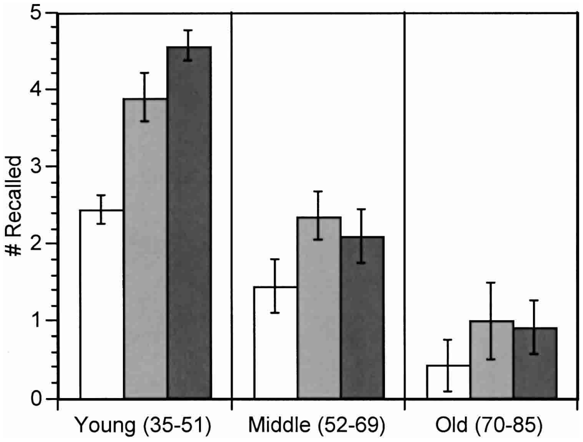

Figure 7. Memory performance for the long-term follow-up recall task. Mean (± standard error) number of slides correctly recalled are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli; pound sign = number.

both the middle-aged ($p < .05$) and older ($p < .005$) groups. Recall performance was not significantly different between the middle-aged and older groups ($p = .12$). Additionally, there was a significant effect of valence ($\lambda = 0.77$), $F(2, 36) = 5.5, p < .01, \eta^2 = 0.23$, in which both positive and negative stimuli were recalled better than neutral stimuli (ps $< .02$). There was no overall gender difference in free-recall performance, $F(1, 37) = 2.5, p = .12, \eta^2 = 0.06$; nor any significant interactions involving gender.

Cued recall. Again, the pattern of results for the cued recall at long-term follow-up was similar to that observed for cued recall at 24 hr, except for an overall diminution in performance (see Figure 8). There was not a significant effect of valence ($\lambda = 0.98$), $F(2, 36) < 1, p > .7, \eta^2 = 0.02$; nor was there a significant Age × Valence interaction ($\lambda = 0.89$), $F(4, 72) = 1.1, p > .3, \eta^2 = 0.06$. There was a main effect of age group, $F(2, 37) = 4.8, p < .05, \eta^2 = 0.21$. Contrasts illustrated that the young group had significantly better performance than both the middle-aged ($p < .005$) and older groups ($p < .01$); the difference between the older and middle-aged groups did not reach statistical significance ($p > .05$). There were no gender differences in performance, $F(1, 37) = 2.3, p = .1, \eta^2 = 0.06$; nor were there any significant interaction effects involving gender.

Yes–no recognition. Because of experimenter error, data from only 11 of the 12 members of the returning older group were available (see Figure 9). There was not a group difference in the pattern of recognition performance (Age × Valence interaction: $\lambda = 0.99$), $F(2, 35) < 1, p > .6, \eta^2 = 0.02$. As in free and cued recall, there was a significant effect of age group, $F(2, 36) = 4.2, p < .05, \eta^2 = 0.19$. Contrasts revealed that the young group recognized significantly more pictures than did the older group ($p < .05$), whereas the middle-aged group was not different from either the young or the older group (ps $> .05$). There was not a significant effect of valence ($\lambda = 0.88$), $F(2, 35) = 2.4, p = .1, \eta^2 = 0.12$. We found no gender differences in overall levels or patterns of performance (Fs < 1).

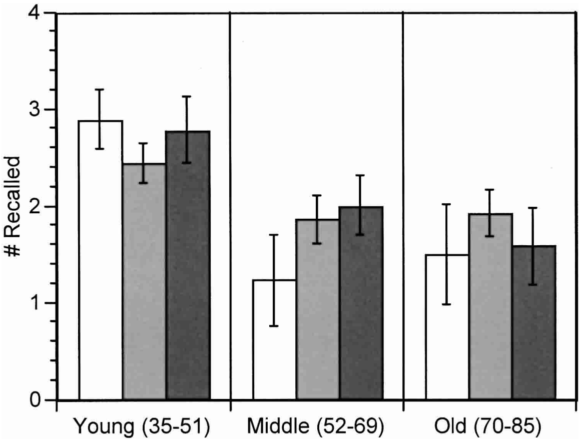

Figure 8. Memory performance on the long-term follow-up cued recall task. Mean (± standard error) number of correct responses are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli; pound sign = number.

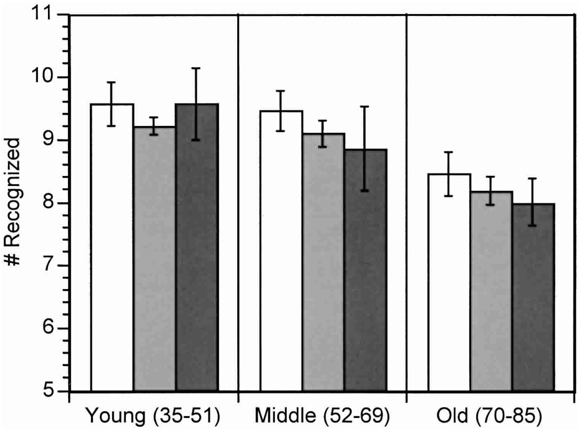

Figure 9. Memory performance on the long-term follow-up yes/no recognition task. Mean (± standard error) number of correct responses are shown. Data are presented by age group and by valence category. Open bars represent neutral stimuli; gray bars represent positive stimuli; solid bars represent negative stimuli; pound sign = number.

Post Hoc Analyses

To further examine the issue of whether the effects of emotional valence on memory were modulated by age, we conducted some post hoc analyses. For the 24-hr free-recall data (see Figure 4) and the 24-hr recognition data (see Figure 6), we computed separate one-way ANOVAs for each age group, with the three valence levels serving as a within-subjects independent variable. For the free-recall data, the effect of valence was highly significant in all of the age groups (ps $< .001$), with the following effect sizes: young, $\eta^2 = 0.67$; middle-aged, $\eta^2 = 0.55$; older, $\eta^2 = 0.45$. For the recognition data, the effect of valence was again highly significant in all of the age groups (ps $< .005$), with the following effect sizes: young, $\eta^2 = 0.43$; middle-aged, $\eta^2 = 0.37$; older, $\eta^2 = 0.40$. All of these effect sizes fall in what can be termed the *moderate* category, and more importantly, the effect size magnitudes are comparable across the different age groups for each of the memory measures. In summary, these post hoc analyses provide further evidence that the effects of emotional valence on memory were similar across the age span.

Discussion

Across a variety of memory measures and two different delay intervals, we failed to find a significant effect of aging on the modulation of memory by emotion. Although older participants showed a general decline in memory relative to younger participants, consistent with extensive literature on this topic (e.g., Zelinski & Stewart, 1998), the different age groups (young, middle-aged, older) showed the same patterns of emotional influence on memory. There were two principal features in these patterns: (a) an “enhancing” effect of emotional arousal on memory for gist, whereby free-recall memory was best for negative stimuli, next-best for positive stimuli, and worst for neutral stimuli; and (b) a “compromising” effect of emotional arousal on memory for detail, whereby forced-choice recognition memory was worst for negative stimuli, next-worst for positive stimuli, and best for neutral stimuli. (In the cued-recall test, thought to combine elements of both gist and visual detail memory, effects of emotional arousal were not manifest, which is consistent with the idea that the enhancing and compromising effects canceled out one another.) In the long-term follow-up, the same patterns of performance were generally obtained, although there was the expected overall decline in memory and some diminution of the emotion effects. Again, the key finding, insofar as the main objective of our study is concerned, is that age did not interact with any of the emotion-related effects.

One important caution on our findings concerns the issue of statistical power. Strictly speaking, our interpretation of the findings as indicating an absence of significant effects of age on emotional modulation of memory depends on the failure to find significant interactions between the factors of age and valence. This, in turn, is influenced by statistical power, and we are very much aware that with very high power (e.g., with triple the present sample size), we may find significant Age × Valence interactions. However, there are several reasons why we believe our findings cannot be dismissed as simply an artifact of low statistical power. First, we had large and essentially equal sample sizes in all age groups (*n*s 26–27). In fact, the effect sizes for many of the significant findings (e.g., main effects of valence on free recall and forced-choice recognition) were at least moderate. Second, the overall patterns of performance on the various memory measures were strikingly similar across age groups, especially at the 24-hr test session. As shown in Figures 4 and 6, the key effects of enhanced memory for gist and compromised memory for visual detail were virtually identical in the different age groups. Thus, despite the fact that the effects of emotional arousal on memory operated in opposite directions for gist versus visual detail, this outcome obtained in all age groups, with exactly the same pattern. Finally, the long-term follow-up assessment indicated some overall persistence of the effects obtained at 24 hr, again, without any modulation by age-related interactions. In short, it seems unlikely that the findings for different types of memory measures and different delay periods would hold so similarly for different age groups, if there was an effect of aging that we were missing just because of low statistical power.

Nevertheless, there are two features of our results that are intriguing and should not be overlooked. First, older participants had lower SCRs to emotionally arousing stimuli (although this difference was not statistically significant). Second, older participants were relatively less influenced by the negatively valenced stimuli; that is, the relative enhancement of gist memory and compromise of visual detail memory was somewhat less pronounced in the older participants, especially at the long-term follow-up, even though this difference did not yield a statistical Age × Valence interaction. These patterns suggest that age was not completely irrelevant in the emotional modulation of memory; for example, it could be the case that older persons are less affected, in certain ways, by negatively valenced stimuli. Be that as it may, though, our data do not point to a prepotent influence of aging because the effect sizes in regard to the impact of emotion on memory were fairly comparable across the three age groups.

It is also important to emphasize that our findings do not appear to be confounded by systematic or potent age-related differences in the emotional value of the stimuli. We have several sources of evidence in this regard, including the ratings of pleasantness and arousal and the skin conductance data. As far as the rating scales are concerned, there is no indication that age made any difference in the manner in which the stimuli were interpreted; for example, all age groups showed the expected outcome of rating the negative pictures as unpleasant and arousing. For the skin conductance, the older participants did have lower SCRs than the younger participants, but this difference was not statistically significant. In short, we have no reason to think that there were major age-related differences in the manner in which the emotional value of the stimuli were interpreted.

It should be clear that we are not claiming that age has no role in emotional modulation of memory. For example, age may have a direct influence, but one that is small and not evident on the measures we used and with the statistical power we had. And there could very well be age-related changes in emotional processing, which has been suggested in previous work (e.g., Gross et al., 1997) and is hinted at in our skin conductance data. In fact, there are many reasons to believe that emotional functioning changes in significant ways across the life span (Blanchard-Fields, 1986; Carstensen, 1993; Carstensen & Turk-Charles, 1994; Labouvie-Vief & DeVoe, 1991; Labouvie-Vief, DeVoe, & Bulka, 1989; Labouvie-Vief, Hakim-Larson, DeVoe, & Schoeberlein, 1989). Furthermore, we are also not claiming that the effects of emotion on memory are equal across age groups—not only is such a claim beyond the scope of our data, but we do not believe it would even turn out to be true because there are ample reasons to expect that the influences of emotion on memory would change, in ways not evident in our experiments, as a function of age. But none of these considerations subverts the main point of our study, which is that emotion modulates memory in a similar way across the adult life span, namely, by enhancing memory for gist and compromising memory for visual detail.

The finding that emotional arousal enhanced memory for gist and compromised memory for visual detail is consistent with a number of previous studies. The general proposal in these studies, which have been conducted in both real-world and laboratory settings, has been that highly emotional material is consolidated in a manner that maximizes memory for gist at the expense of memory for visual detail (Adolphs et al., 2002; Burke et al., 1992; Christianson & Loftus, 1991; Reisberg & Heuer, 1992; Wessel & Merckelbach, 1998). Of our memory tasks, free recall can be considered to assess primarily memory for gist; conversely, the four-alternative forced-choice recognition task can be considered to assess primarily memory for visual details. It is precisely these tasks that showed the pattern expected from prior studies (i.e., negative > positive > neutral for free recall, and neutral > positive > negative for four-alternative forced-choice recognition). Our cued-recall task, however, involved recall of both gist and visual detail information, likely accounting for the lack of a clear effect of emotional valence on performance. It should be understood, however, that the issue of gist versus visual detail in regard to emotional arousal and memory is far from resolved, and more studies on this topic are clearly needed.

Although there were gender differences for some of the ratings of the stimuli (i.e., women rated the stimuli as more arousing and rated negative stimuli as more unpleasant), with one exception (i.e., 24-hr cued recall) we found no gender differences on any of our memory tasks, and the gender differences in the ratings were small in magnitude. The general lack of gender effects supports the idea that the pattern of findings we outline here holds true for both men and women. However, we are well aware that gender effects have been reported in some studies, and our study may have had insufficient power to detect small but reliable effects of gender on some of the measures. For example, a recent study by Cahill et al. (2001) reported differential left versus right amygdala activation related to encoding emotional stimuli in men and women, respectively. Other studies have suggested that this differential amygdala involvement results from differential encoding of gist versus detail information (Kilpatrick & Cahill, 2001). Because we found no gender differences in memory for either gist or visual detail on our tasks, we do not qualify by gender the neuroanatomical explanation we propose immediately below; however, we are very much open to the possibility that further studies will require modifications and elaborations on our explanation.

Our study was not designed to test any anatomical hypotheses, and we have no direct evidence regarding the neuroanatomical status of our participants. Nevertheless, it is tempting to speculate that the basic pattern we found could be indicative of disproportionate age-related decline in different mesial temporal lobe structures. Specifically, the idea is that hippocampal-related structures may be affected more, and the amygdala affected less, and this could provide an explanation for why overall declarative memory declines but the effects of emotional arousal on memory persist. There are a number of convergent sources of evidence that can be marshaled in support of this reasoning, and we review those briefly below.

The idea that the hippocampus is vulnerable to the effects of aging is not new or controversial. First, there is evidence of hippocampal atrophy in the context of normal aging. Golomb et al. (1993) estimated the prevalence of radiographically detectable hippocampal atrophy in a cross-sectional sampling of 154 healthy older adults and found that a high percentage (32.5%) demonstrated significant atrophic changes. A recent study by Jernigan et al. (2001) examined age-associated changes in regional brain volumes in a healthy sample of adults aged 30–99 years and concluded that the rate of loss in the hippocampus exceeded that of gray matter loss elsewhere in the brain. Also, recent work investigating neuropsychiatric disorders (e.g., depression, posttraumatic stress disorder) and prolonged life stress has demonstrated that such factors have adverse effects on the hippocampus (e.g., atrophy, overt neuron loss; Sapolsky, 2000a, 2000b, 2001; for comparable work in animals, see Mabry, Gold, & McCarty, 1995). In addition, in a number of neurodegenerative conditions—most notably Alzheimer's disease—degeneration of the hippocampus is a hallmark feature (e.g., Hyman, Van Hoesen, Damasio, & Barnes, 1984). Finally, it is worth noting that the hippocampus is a brain site that is particularly vulnerable to a host of neurological insults, including herpes simplex encephalitis and anoxia/ischemia (Tranel, Damasio, & Damasio, 2000).

Evidence for comparable age-related effects on the amygdala is less convincing. A few studies have shown that aging can affect the volume and morphology of the amygdala. For example, magnetic resonance-based measurements of the amygdala have demonstrated decreases in volume with age in a linear fashion for each successive decade from age 60 to age 90, with a strong negative correlation ($r = -.92$; Mu, Xie, Wen, Weng, & Shuyun, 1999). Similarly, Smith et al. (1999) compared healthy older adults (mean age of 73) with their younger counterparts (mean age of 27) and found statistically significant decreases in volume measures of the left (21% reduction) and right (14% reduction) amygdala. A decrease in volume of the amygdala with advancing age was also demonstrated in another sample of normal older participants (Jack et al., 1997). Overall, though, this literature is considerably less developed than that regarding the hippocampus, leaving open the possibility that the amygdala may be less vulnerable to untoward effects of aging, and may support full functional capacities later into the life span.

If there is some correctness to this reasoning—that the hippocampal system is affected more and/or earlier by the aging process than is the amygdala—this leads to a potential neuroanatomical explanation for the emotion-related findings we report in this study. The proposal is as follows: A large number of animal studies have demonstrated that the amygdala is a key structure that mediates the effects of emotion on memory, and that it does so via a time-dependent modulation of hippocampal function (Bianchin, Mello e Souza, Medina, & Izquierdo, 1999; Cahill & McGaugh, 1998; Packard, Cahill, & McGaugh, 1994). Whereas hippocampal-dependent processes subserve encoding and consolidation irrespective of the emotional nature of the material (e.g., Alkire, Haier, Fallon, & Cahill, 1998), the amygdala provides modulation of the hippocampal system during the experience of emotional arousal. Direct dissociations have been documented in animal studies between hippocampal function and its amygdala-dependent modulation (Packard et al., 1994) and between the effects of emotional valence and emotional arousal (Cahill & McGaugh, 1990).

Lesion and functional imaging studies in humans have recently corroborated these earlier findings from animal models. Although damage to the hippocampal formation appears to have no effect on the modulation of memory by emotion, as demonstrated by preserved emotional memory in participants with amnesia (Hamann et al., 1997), patients with brain damage involving the amygdala do not experience the same benefit from emotionally arousing material (Adolphs, Cahill, Schul, & Babinsky, 1997; Adolphs et al., 2000; Cahill, Babinsky, Markowitsch, & McGaugh, 1995; Hamann & Adolphs, 1999; LaBar, Gatenby, Gore, LeDoux, & Phelps, 1998). In effect, bilateral damage to the amygdala abolishes the booster effect of emotionally arousing events, rendering their memorability comparable to that of neutral events. Functional imaging studies have demonstrated a positive correlation between amygdala activation at the time that emotional stimuli were first encoded and subsequent (days to weeks) long-term declarative memory for the same stimuli (Cahill et al., 1996; Canli et al., 2000; Hamann, Ely, et al., 1999). Moreover, such correlations with amygdala activation have been obtained for stimuli possessing either positive or negative valence (Hamann, Ely, et al., 1999). By contrast, activation of the hippocampus during encoding is correlated with later recall of emotionally *neutral* stimuli (Alkire et al., 1998).

To summarize, our finding that the emotional modulation of memory is not substantially affected by the aging process can be explained in terms of differential aging of hippocampal structures versus the amygdala. This proposal is open to empirical verification, of course, and we have no direct evidence from our study one way or another. But the overall idea is appealing, especially given the intriguing recent findings of how the amygdala seems to mediate various effects of emotion on declarative memory. And the idea has potential ramifications for management and treatment; for example, adding emotional connotation to memory material could palliate age-related declines in declarative memory.

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