Effects of Normal Aging and Alzheimer's Disease on Emotional Memory

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Recall is typically better for emotional than for neutral stimuli. This enhancement is believed to rely on limbic regions. Memory is also better for neutral stimuli embedded in an emotional context. The neural substrate supporting this effect has not been thoroughly investigated but may include frontal lobe, as well as limbic circuits. Alzheimer's disease (AD) results in atrophy of limbic structures, whereas normal aging relatively spares limbic regions but affects prefrontal areas. The authors hypothesized that AD would reduce all enhancement effects, whereas aging would disproportionately affect enhancement based on emotional context. The results confirmed the authors' hypotheses: Young and older adults, but not AD patients, showed better memory for emotional versus neutral pictures and words. Older adults and AD patients showed no benefit from emotional context, whereas young adults remembered more items embedded in an emotional versus neutral context.

Declarative memory for emotional stimuli (positive and negative) is typically better than memory for neutral stimuli (Hamann, Cahill, McGaugh, & Squire, 1997; Hamann, Cahill, & Squire, 1997; Heuer & Reisberg, 1990; Phelps, LaBar, & Spencer, 1997). Individuals tend to recall more positive and negative items than neutral items (see Hamann, 2001, for review), and are better able to recall the source of emotional than neutral items (Doerrksen & Shimamura, 2001), and are more likely to "remember" in vivid detail negative items than neutral items (Ochsner, 2000). Patients with amygdala lesions, however, often do not show this memory enhancement effect (Adolphs, Cahill, Schul, & Babinsky, 1997; Adolphs, Tranel, & Denburg, 2000; Cahill, Babinsky, Markowitsch, & McGaugh, 1995; Phelps et al., 1997). In contrast, amnesic patients with damage to medial temporal lobe structures beyond the amygdala do show the enhancement effect (Hamann, Cahill, McGaugh, & Squire, 1997; Hamann, Cahill, & Squire, 1997). These results indicate that the declarative-memory enhancement effect is particularly reliant on the amygdala. Further evidence for the amygdala's role in this effect comes from neuroimaging studies showing that amygdaloid activation during encoding of emotional stimuli, but not neutral stimuli, is predictive of subsequent
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Memory Enhancement in Mild Alzheimer's Disease

The volume of the amygdala shrinks in Alzheimer's disease (AD; Chan et al., 2001; Galton et al., 2001; Jack et al., 1999; Scott, DeKosky, & Scheff, 1991; Smith et al., 1999), and this atrophy is pronounced even in the early stages of the disease (Krasuski et al., 1998; Mizuno, Wakai, Takeda, & Sobue, 2000). Microscopically, neuritic plaques are abundant in the amygdala (Unger, Lapham, McNeill, Eskin, & Hamill, 1991), and neurofibrillary tangles are plentiful as well (Arriagada, Growdon, Hedley-Whyte, & Hyman, 1992; Vogt, Human, Van Hoesen, & Damasio, 1990). It is an open question as to whether this pathology disrupts the memory enhancement effect. Some researchers have reported spared emotional enhancement in patients with AD for a real-life traumatic event (e.g., an earthquake: Ikeda et al., 1998), and for emotional versus neutral stories (Kazui et al., 2000; Moayeri, Cahill, Jin, & Potkin, 2000). Other researchers have reported impaired emotional enhancement effects for negative photographs but preserved enhancement for positive photographs (Hamann, Monarch, & Goldstein, 2000). Although AD patients also have hippocampal atrophy, it appears that amygdaloid and not hippocampal damage accounts for the emotional enhancement reductions: Amygdaloid volume, rather than hippocampal volume, best predicts memory for an emotional event in patients with AD (Mori et al., 1999). The fact that amnesic patients with lesions in the hippocampal formation (but not the amygdala) can show normal emotional-memory enhancement effects (Hamann, Cahill, McGaugh, & Squire, 1997; Hamann, Cahill, & Squire, 1997) also suggests that any emotional memory disruption in AD is not due to hippocampal lesions.

One goal of the present study was to examine whether patients in an early stage of AD would show spared or impaired memory enhancement for emotional (positive and negative) items compared with neutral items. This finding would indicate whether damage to the amygdala in AD is sufficient to cause reductions in the emotional-memory enhancement effect. As a corollary of this goal, we sought to determine whether AD differentially affected memory for negative compared with positive stimuli. Neuroimaging studies have found contradictory results with regard to whether amygdaloid activation correlates with subsequent memory for positive stimuli as well as negative stimuli. If the amygdala plays a lesser role in memory for positive than for negative stimuli, then AD patients could show a disproportionate impairment in remembering negative stimuli. This study also has direct clinical relevance by clarifying the issues that compound memory deficits in AD. Because episodic memory loss is the hallmark of AD, it is critical that we understand the different dimensions of that memory loss, and whether any episodic memory components, such as emotional memory, are relatively preserved.

Memory Enhancement With Normal Aging

In contrast to AD, normal aging relatively spares limbic regions, including the amygdala (Insauri, Insauri, Sobreviela, Salinas, & Martinez-Penuela, 1998). Only modest reductions in amygdaloid volume occur with normal aging (Smith et al., 1999). It is not known whether this volumetric reduction causes functional deficits, such as reducing the emotional-memory enhancement effect. Although prior studies have shown that older adults benefit from the emotional valence and arousal level of stimuli (Hamann et al., 2000; Kazui et al., 2000), to our knowledge no studies have compared emotional memory in young and older adults. Thus, the second goal of this study was to assess whether the emotional-memory enhancement effect would be as great in older adults as in young adults.

Memory Enhancement for Neutral Stimuli Embedded in an Emotional Context

Memory for neutral stimuli embedded in an emotional context is superior to memory for neutral stimuli embedded in a neutral context. For example, if some individuals watch a movie with a negative scene...
embedded in it, and others watch the same movie without the negative scene, those who watched the emotional version are better able to recall not only the critical scene but also the neutral context surrounding that scene. The neutral substrate underlying improved memory for neutral stimuli in an emotional context is uncertain but may rely on different structures from the memory enhancement to emotional stimuli. Specifically, we hypothesized that this enhancement effect may benefit from frontal lobe as well as limbic processes. Because the frontal lobe (in particular, prefrontal cortex) is critical for binding items to their context ("source memory": Craik, Morris, Morris, & Loewen, 1990), it seems a likely candidate to subserve some of the memory enhancement for neutral stimuli embedded in an emotional context. To date, only two neuroimaging studies have investigated this effect, and these studies provide evidence for a role of the frontal lobe in retrieving information presented in an emotional context (Maratos, Dolan, Morris, Henson, & Rugg, 2001; Maratos & Rugg, 2001). The ability to recollect information presented in an emotional context, therefore, appears to recruit frontal lobe circuits, though it is unclear whether these circuits are necessary for the memory enhancement to occur.

Aging results in structural changes in the frontal lobe, including atrophy and white matter changes (Double et al., 1996; Raz, Briggs, Marks, & Acker, 1999). In fact, of all brain regions, the frontal lobe shows the greatest volumetric differences between young and older adults (Coffey et al., 1992). In addition to volumetric changes, the frontal cortex also shows hypometabolism in older adults (Moeller et al., 1996). Functional changes also exist, including declines in frontal lobe blood flow that have been shown in cross-sectional (Mamo, Meric, Laft, & Seylaz, 1983; Tachibana et al., 1984) and longitudinal studies (Tachibana et al., 1984). Frontal dysfunction in aging is also evidenced by reduced performance on frontal lobe tasks such as the Stroop test (Stroop, 1935). Wisconsin Card Sorting Test (Heaton, 1981), or tests of source memory (Chao & Knight, 1997; Cohn, Dustman, & Bradford, 1984; Grady & Craik, 2000; Spencer & Raz, 1994, 1995; Spieler, Balota, & Faust, 1996). If the enhancement effect for neutral stimuli in an emotional context requires frontal lobe processes, in addition to limbic processes, then older adults should show less enhancement when remembering the context surrounding an emotional event relative to memory for the emotional event itself.

The third goal of this study was, therefore, to discover whether normal aging would disproportionately impair memory for the contextual stimuli surrounding an emotional item compared with memory for the emotional item itself.

Method

Participants

The participants were 20 young adults, 20 older adults, and 13 patients with early AD (Table 1). AD participants were referred to the study from the Memory Disorders Unit at the Massachusetts General Hospital. The clinical diagnosis of AD was established in accordance with the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; 4th ed.; American Psychiatric Association, 1994) and the National Institute of Neurological and Communicative Disorders and Stroke, and the Alzheimer’s Disease

<table>
<thead>
<tr>
<th>Variable</th>
<th>Young</th>
<th>Older</th>
<th>AD</th>
<th>Young</th>
<th>Older</th>
<th>AD</th>
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<td>0.85</td>
<td>0.6</td>
<td>1.2</td>
<td>0.9</td>
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</tr>
<tr>
<td>Blessed Dementia Scale</td>
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<td></td>
<td></td>
<td>0.4</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
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</table>

Note. The young adult and older adult group included 9 men and 11 women; for the Alzheimer’s disease (AD) patients, there were 7 men and 6 women. WAIS-III = Wechsler Adult Intelligence Scale (3rd ed.); Vocab. = Vocabulary. Dashes indicate that data were not obtained.

* Based on Information, Memory, and Concentration section (Blessed, Tomlinson, & Roth, 1968).
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and Related Disorders Association (McKhann et al., 1984) criteria. AD patients were all taking donepezil but were not taking any other medications (e.g., antidepressants, anxiolytics) that could affect cognition. Donepezil is a cholinesterase inhibitor that modestly improves cognition in some patients with mild to moderate AD (Greenberg et al., 2000; Rogers, Farrow, Doody, Mohs, & Friedhoff, 1998). Young and older adults were recruited through fliers posted throughout the Boston–Cambridge area and through the Harvard Cooperative on Aging. All participants were screened to eliminate those with a history of alcoholism, major heart disease, cancer, or neurological or psychiatric disorders other than the primary diagnosis of AD. No participants were depressed. All scores on the Geriatric Depression Scale, Short Form (Sheikh & Yesavage, 1986) were less than 4 (scores less than 7 are considered not depressed).

Emotional Memory Tasks

We administered two tests of memory for emotional stimuli and two tests of memory for neutral stimuli embedded in an emotional context. Older adults were also administered three tests of source memory. Testing required 2–3 hr for young adults and AD patients and 3–4 hr for older adults. Participants were given breaks approximately every hour, including an hour break for lunch; they were remunerated at a rate of $10/hr.

Recall of Neutral and Emotional Words

Participants viewed 27 words for 3 s each on a computer screen and were asked to rate each word as positive, negative, or neutral. The nine positive and nine negative words, taken from the Affective Norms for English Words (ANEW, Bradley & Lang, 1999), were selected to have high arousal and high or low valence, respectively. The positive and negative words were matched for word length, frequency, arousal, and absolute valence. The nine neutral words were matched to the emotional words in length, frequency, and familiarity (Coltheart, 1981; Kucera & Francis, 1967). Consistent with these objective ratings of the words, participants on average subjectively rated nine words as neutral, nine words as positive, and nine words as negative. There was no evidence of rating differences among the three groups.

To avoid ceiling or floor effects, young adults viewed the set of words once, and older adults and AD patients viewed the words twice. Participants were then given a recall test, in which they were asked to write all the words they remembered. Scores were calculated in two ways: first, as the percentage of correctly recalled words that were rated in the IAPS (Lang et al., 1999) as (a) positive and high arousal, (b) positive and low arousal, (c) neutral and high arousal, (d) neutral and low arousal, (e) negative and high arousal, or (f) negative and low arousal; and second, as the percentage of responses describing stimuli rated by the participant as positive, negative, or neutral (e.g., if a participant recalled 20 pictures and had rated 5 of those pictures as “positive,” the recall score for positive pictures would be 5/20 or 25%).

Recall of Neutral and Emotional Pictures

Participants viewed 45 pictures for 5 s each on a computer screen and rated each picture as positive, negative, or neutral. Positive and negative pictures were matched for absolute valence, and all pictures were matched for arousal level with the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). According to the IAPS ratings, 15 pictures were positive (7 relatively high arousal, 8 relatively low arousal), 15 were negative (7 relatively high arousal and 8 relatively low arousal), and 15 were neutral. Consistent with these objective ratings, participants subjectively rated approximately 15 pictures as positive, 15 as negative, and 15 as neutral. There were no significant rating differences among the young adults, older adults, and AD patients. To avoid ceiling or floor effects, young adults viewed the set of pictures one time; older adults and AD participants viewed the pictures two times. Participants were then given a recall test, in which they were asked to write a brief description of all the pictures they remembered. Scores were calculated in two ways: first, as the percentage of correctly recalled pictures that were rated in the IAPS (Lang et al., 1999) as (a) positive and high arousal, (b) positive and low arousal, (c) neutral and high arousal, (d) neutral and low arousal, (e) negative and high arousal, or (f) negative and low arousal; and second, as the percentage of responses describing stimuli rated by the participant as positive, negative, or neutral (e.g., if a participant recalled 20 pictures and had rated 5 of those pictures as “positive,” the recall score for positive pictures would be 5/20 or 25%).

Recall of Neutral Words Embedded in a Positive, Negative, or Neutral Context

Participants viewed 30 neutral words (e.g., trunk, wagon, statue) for 3 s each on a computer screen and generated a sentence using each of the words. For 10 of the words, the sentence was to be neutral in valence (e.g., “The trunk in the basement was painted red and
blue.”); for 10 other words, the sentence was to be positive (e.g., “The boy was very happy with his new, red wagon.”); and for the remaining 10 words, the sentence was to be negative (e.g., “Graffiti covered the once beautiful statue.”). The groups of 10 words were matched for word frequency, word length, and familiarity (Coltheart, 1981; Kučera & Francis, 1967); the groups used to generate positive, negative, and neutral sentences were counterbalanced across participants.

Three independent raters, unaware of the participant groups, rated the sentences from all of the participants in random order. They were asked to rate each sentence on a scale from 1 to 10 (1–2 = highly negative, 3–4 = somewhat negative, 5–6 = neutral, 7–8 = somewhat positive, and 9–10 = highly positive). We took the average of the three ratings and used those averages to determine whether the participant groups differed in the positivity or negativity of the contexts they generated. The groups did not differ in the number of sentences assigned by the raters to a particular category (e.g., somewhat positive), suggesting that the amygdaloid atrophy present in AD, and the frontal atrophy present in normal aging, do not disrupt the ability to generate emotional contexts.

After generating the 30 sentences, participants were asked to write all of the words for which they generated sentences. Scores were calculated in two ways: first, as the percentage correct for words used to generate sentences rated by the independent raters as (a) highly negative, (b) somewhat negative, (c) neutral, (d) somewhat positive, or (e) highly positive; and second, as the percentage of correctly recalled items that were words the participant was asked to use in a positive, negative, or neutral sentence (e.g., if a participant recalled 10 words and had been instructed to use 1 of the words in a neutral sentence, the score for neutral context would be 1/10 or 10%).

**Recognition of Neutral and Negative Words and of Neutral Words Embedded in a Neutral or Negative Context**

Because older adults may be disproportionately impaired on recall versus recognition (Craik, Byrd, & Swanson, 1987), we wanted to include a recognition test that would assess memory for (a) emotional versus neutral items, and (b) neutral items embedded in an emotional versus neutral context. In this task, participants read each of 42 sentences aloud. Sentences were either neutral or negative. Across participants, the sentences were counterbalanced such that half the participants read the neutral version of the sentence (e.g., “The sailor was responsible for the dock”), while the other half read the emotional version (e.g., “The sailor was responsible for the rape”). The emotional sentences were constructed by using emotionally aversive words with a high score for “arousal” and a low score for “valence” selected from ANEW (Bradley & Lang, 1999). Neutral words were matched in length and to within 1 3D of each of the emotional words for frequency (Kučera & Francis, 1967), imagability, concreteness, and familiarity (using the MRC psycholinguistic database; Coltheart, 1981) to create 42 matched-sentence pairs.

To avoid ceiling or floor effects, young adults performed a three-choice recognition test after a 1-h delay, whereas older adults and AD patients took the test after a 5-min delay. Half the recognition items asked about an emotional or neutral word (e.g., dock or rape), whereas the other half asked about a neutral word that had been embedded in either an emotional or neutral context (e.g., sailor). The two distractors were selected from the MRC database and were matched to within 1 SD of the target word for frequency, imagability, concreteness, and familiarity. These distractor words also had valences similar to those of the target words. The recognition test was scored for (a) percentage of neutral items recognized (e.g., dock); (b) percentage of negative items recognized (e.g., rape); (c) percentage of neutral context words recognized from a neutral sentence (e.g., sailor, in the neutral sentence); and (d) percentage of neutral context words recognized from a negative sentence (e.g., sailor, in the negative sentence).

**Source Memory Tests**

**Actions Test**

This test was adapted from Cohen and Faulkner (1989) and Guttentag and Hunt (1988). A 6 × 6 grid was laid out in front of the participant, with a common object in half of the grid locations. Three blocks (each with different objects) of nine actions each were read to the participants who were instructed to remember the actions. Each action required spatial manipulation of two common objects. Participants were asked to imagine, perform, or watch the action (e.g., “place the calculator to the right of the lipstick.” “imagine that you place the book under the pencil,” “watch as I place the cassette tape on top of the can”). The action methods (imagine, perform, watch) were randomized within each of the blocks. Across participants, we
counterbalanced for block order, within-block action order, and the method associated with each action. A recognition test with 41 items (the 27 old actions and 14 new actions) was administered immediately after all three sets were completed, and participants were asked to determine whether the action occurred and the method by which it occurred. All lures included objects placed on the grid, but with manipulations that had never been presented (e.g., “place the calculator to the left of the pencil”). The test was scored for (a) the percentage of actions correctly recognized (hits – false alarms) and (b) percentage of actions for which the correct method was indicated.

**Memory for Temporal Order**

Participants listened to a list of 25 words, presented at a rate of 1 word every 2 s, with the knowledge that they would be asked to recognize the words later. After a 5-min delay, 40 words were presented orally and the participant indicated (a) whether the word was in the list and (b) its location in the list (first, middle, or last third). The test was scored for (a) percentage of items correctly recognized (hits – false alarms), and (b) percentage of items attributed to the correct part of the list.

**Fictitious Facts**

This test was based on previous work by Schacter, Kaszniak, Kihlstrom, and Valdiserri (1991) and Spencer and Raz (1994). The stimuli were 36 facts, of which 27 were fictitious (e.g., Angela Lansbury regularly consults with astrologists). The facts were presented on alternating blue-and-pink index cards. Participants viewed the cards, one at a time, and read them silently while two experimenters, alternating after every nine cards, read the facts. Then, participants rated each fact for its believability. After a 1.5-hr delay, they completed a questionnaire of fact memory (“Angela Lansbury regularly consults who?”) and source memory (“Did you learn this fact from the experiment? If so, on what color card was the fact written?” “Did the woman with the dark or light hair read you the fact?”). The test was scored for (a) percentage of fictitious facts correctly recalled, (b) percentage of fictitious facts correctly attributed to the experiment, (c) percentage of fictitious facts attributed to the correct colored card (pink or blue), and (d) percentage of fictitious facts attributed to the correct experimenter (light or dark hair). Participants had never seen either of the experimenters before the beginning of this test, and they did not interact with them until after the recognition test had been completed.

**Data Analysis**

Analyses of variance (ANOVAs) and t tests were computed separately for each task, and separately for young versus older adults and older adults versus AD patients. ANOVAs included group (young adult, older adult, AD) as a between-subjects factor and item type (positive, negative, neutral), arousal level, and valence level as within-subjects factors. For older adults, Pearson correlation coefficients were computed between (a) memory for emotional versus neutral stimuli, or memory for neutral stimuli in an emotional versus neutral context; and (b) performance on source memory tasks. All reported p values are two-tailed. Tables 2-5 display the percentage of correct responses for each of the objectively measured conditions of the experiments. Figures 1-3 show the percentage of correctly recalled items from each subjectively measured experimental condition (i.e., the values of the three bars account for all the correct recall responses and sum to 100%).

**Results**

**Picture Recall**

**Young and Older Adults**

*Scores based on objective picture ratings.* When the data were analyzed as the percentage correctly recalled for pictures of a particular rating from the IAPS (e.g., high arousal, high valence), ANOVAs indicated an effect of arousal (high, low; p < .0001) and valence (positive, negative, neutral; p < .001), but not age group (p > .7). ANOVAs indicated no significant interactions (p > .4). Post hoc t tests indicated that young and older adults recalled significantly more high-arousing than low-arousing stimuli (p < .01), and more high valence than neutral (p < .01) and more low valence than neutral (p < .01) pictures (Table 2). Overall, the two groups did not differ in the total number of pictures recalled (p > .03), nor did they differ in the percentage recalled for pictures of any valence and arousal combination as rated in the IAPS (e.g., low arousal, high valence; p > .3).

*Scores based on subjective picture ratings.* When the data were analyzed as the percentage of recalled items that had been subjectively rated by the participant as neutral, positive, or negative. ANOVAs indicated an effect of item type (neutral, positive, or negative; p < .0001), but no effect of group and no Group
Table 2
*Picture—Recall Test: Mean Percentage Correct (± SD) for Objective Item Classifications*

<table>
<thead>
<tr>
<th>Group</th>
<th>High valence</th>
<th>Low valence</th>
<th>Neutral</th>
<th>High valence</th>
<th>Low valence</th>
<th>Neutral</th>
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</thead>
<tbody>
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<td>Young adults</td>
<td>60.7 (30.3)</td>
<td>66.4 (19.4)</td>
<td>40.7 (23.3)</td>
<td>48.1 (24.1)</td>
<td>54.3 (21.0)</td>
<td>29.3 (15.0)</td>
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<tr>
<td>Older adults</td>
<td>69.3 (25.5)</td>
<td>64.3 (25.0)</td>
<td>37.1 (16.3)</td>
<td>50.6 (21.6)</td>
<td>56.3 (23.2)</td>
<td>26.3 (14.6)</td>
</tr>
<tr>
<td>AD patients</td>
<td>23.8 (16.0)</td>
<td>25.4 (25.5)</td>
<td>22.2 (17.5)</td>
<td>15.9 (8.6)</td>
<td>23.8 (17.7)</td>
<td>23.8 (26.7)</td>
</tr>
</tbody>
</table>

*Note.* Valence and arousal categories determined from the International Affective Picture System (Lang et al., 1999).

× Item Type interaction. Post hoc t tests indicated that for young and older adults, a significantly larger proportion of recalled pictures was positive than neutral (p < .001) and negative than neutral (p < .001, see Figure 1). There was no difference for either age group in the percentage of responses that were positive versus negative (p > .15).

These results indicate that the young and older adults showed similar declarative-memory enhancement effects for positive and negative items compared with neutral items. The results were similar regardless of whether objective ratings taken from the IAPS (Lang et al., 1999) or subjective participant ratings were used.

**Older Adults and AD Patients**

Scores based on objective picture ratings. *t* tests indicated that, overall, older adults recalled significantly more pictures than the AD group (p < .0001). This difference remained significant for all of the arousal and valence conditions (p < .05), with the exception of the low arousal and no valence condition, where the older adults and AD participants performed similarly (p > .5; see Table 2).

When the data were analyzed using the percentage of recalled pictures with a particular rating from the IAPS, ANOVAs indicated an effect of group (p < .0001), arousal (p < .05), and valence (p < .01), an interaction between group and valence (p < .001) but not between group and arousal (p > .15), arousal and valence (p > .3), or age group, arousal, and valence (p > .6). Post hoc *t* tests indicated that only the older adults, and not the AD patients, recalled a greater number of positive or negative valence items compared with neutral items. In contrast, both groups recalled a greater number of high-arousing than low-arousing items (p < .01). When the data were analyzed separately for positive, negative, and neutral items, however, we found that the AD group showed significantly better memory for the high arousal, high valence pictures than for the low arousal, high valence pictures (p < .001), but no memory modulation based

![Figure 1](https://example.com/image.png)

*Figure 1.* Picture recall: Of the pictures recalled by young and older adults, a significantly greater percentage were pictures subjectively rated by each participant as positive or negative. The Alzheimer’s disease (AD) group, in contrast, gave an equal percentage of recall responses to pictures rated as positive, negative, and neutral. Error bars indicate ± 1 SE. Stars indicate significant differences compared with the neutral picture condition (p < .05).
on arousal for the low valence or neutral items. Their memory performance for the high arousal, high valence items also did not differ significantly from their performance for low arousal, neutral items, or low arousal, negative items. These results suggest that the AD group did not show the consistent memory enhancement on the basis of arousal that was seen in the older adult group.

**Scores based on subjective picture ratings.** When the data were analyzed using the percentage of recall responses given to pictures subjectively rated by the participant as neutral, positive, or negative, ANOVAs indicated no effect of group (p > .15), a significant effect of item type (p < .0001), and a significant Group × Item Type interaction (p < .005). Post hoc t tests showed that older adults, compared with AD patients, gave a marginally larger percentage of recall responses to negative pictures (p < .10, see Figure 1) and positive pictures (p < .10, see Figure 1), and a smaller percentage of recall responses to neutral pictures (p < .01, see Figure 1).

The results show that AD patients did not benefit from the emotional valence of the pictures. This conclusion holds for analyses on the basis of subjective as well as objective picture ratings.

**Word Recall**

**Young and Older Adults**

**Scores based on objective word ratings.** When the data were analyzed using the percentage correctly recalled for positive, negative, and neutral words, as rated in ANEW (Bradley & Lang, 1999), ANOVAs indicated an effect of item type (positive, negative, neutral; p < .0001), no effect of age group (p > .4), and no Age Group × Item Type interaction (p > .5). Post hoc t tests indicated that young and older adults showed a memory benefit for positive and negative stimuli compared with neutral stimuli (p < .05). Young and older adults did not differ in the total number of words recalled (p > .3), nor did they differ in the number of recall responses given to positive, negative, or neutral words recalled (p > .3; see Table 3).

**Scores based on subjective word ratings.** When the data were analyzed using the percentage of recall responses given to words rated as neutral, positive, or negative, ANOVAs indicated an effect of item type (positive, negative, neutral; p < .0001), no effect of group (p > .8), and a marginally significant Group × Item Type interaction (p < .10). Older adults showed better memory for negative than for positive stimuli, whereas young adults showed the reverse pattern (Figure 2). When positive and negative stimuli were collapsed into an emotional item category, ANOVAs indicated an effect of item type (emotional, neutral; p < .0001), no effect of group (p > .15), and no Group × Item Type interaction (p > .2).

These results indicate that young and older adults showed better memory for positive and negative words than for neutral words. Both groups showed a similar magnitude of memory enhancement, regardless of whether the data were analyzed by objective or subjective ratings.

**Older Adults and AD Patients**

**Scores based on objective word ratings.** When the data were analyzed using the percentage correctly recalled for positive, negative, and neutral words (as rated in ANEW), ANOVAs indicated a marginal effect of item type (positive, negative, neutral; p < .1), a significant effect of group (p < .0001), and a significant Group × Item Type interaction (p < .05). Older adults recalled a significantly larger number of words than AD patients (p < .0001). The two groups recalled a similar number of neutral words (p > .1), but the older adults recalled significantly more positive words (p < .001) and negative words (p < .0001; see Table 3).

**Scores based on subjective word ratings.** When the data were analyzed using the percentage of recall responses given to pictures subjectively rated as neutral, positive, or negative, ANOVAs indicated no effect of group (p > .15), a marginal effect of item type (p < .10), and a significant Item Type × Group interaction (p < .0001). Post hoc t tests

<table>
<thead>
<tr>
<th>Group</th>
<th>High valence</th>
<th>Low valence</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young adults</td>
<td>45.6 (16.2)</td>
<td>39.7 (23.1)</td>
<td>24.6 (11.9)</td>
</tr>
<tr>
<td>Older adults</td>
<td>37.9 (21.7)</td>
<td>39.8 (11.8)</td>
<td>23.5 (7.9)</td>
</tr>
<tr>
<td>AD patients</td>
<td>18.4 (8.7)</td>
<td>13.0 (10.0)</td>
<td>17.6 (10.2)</td>
</tr>
</tbody>
</table>

*Note.* Valence categories determined from the Affective Norms for English Words (Bradley & Lang, 1999).
indicated that the two groups recalled a similar percentage of items rated as positive \((p > .15, \text{see Figure 2})\), the older adults recalled a marginally lower percentage of items rated as neutral \((p < .10, \text{see Figure 2})\), and a greater percentage of items rated as negative \((p < .005, \text{see Figure 2})\) than the AD group. When negative and positive items were combined in an emotional item category, ANOVAs indicated no effect of group \((p > .15)\), a marginal effect of item type \((p < .10)\), and a significant Item Type \(\times\) Group interaction \((p < .05)\).

These results indicate that the AD group did not show a memory benefit for the emotional words, whereas the older adults showed improved memory for negative and positive words compared with neutral words. These results were consistent across objective and subjective ratings of the stimuli.

**Sentence Generation: Recall of Words From Neutral or Emotional Contexts**

**Young and Older Adults**

Scores based on independent ratings of sentence contexts. When analyses were conducted on the percentage correct for words used in sentences independently rated as neutral, somewhat positive, highly positive, somewhat negative, or highly negative, ANOVAs indicated a significant effect of group \((p < .001)\), a marginal effect of item type \((p < .1)\), and a marginal Group \(\times\) Item Type interaction \((p < .1)\). When the data were analyzed using only the sentences rated as neutral, highly negative, or highly positive, ANOVAs indicated a significant effect of group \((p < .001)\), a significant effect of item type \((p < .05)\), and a significant Group \(\times\) Item Type interaction \((p < .05)\). Post hoc \(t\) tests indicated that young adults recalled significantly or marginally significantly more words from sentences rated as somewhat or highly positive or negative than from sentences rated as neutral \((p < .1)\). The older adults, in contrast, showed no memory modulation on the basis of sentence context \((p > .5)\). Overall, the older adults recalled fewer words than the young adults \((p < .01)\). Young and older adults recalled an equal number of neutral words used in neutral sentences \((p > .1)\), but young adults recalled significantly more words used in positive or negative contexts \((p < .05; \text{see Table 4})\).

Scores based on subjective sentence contexts. When the data were analyzed on the basis of the percentage of participants' recall responses given to words that they had been instructed to use in a neutral, positive, or negative sentence, \(t\) tests indicated that young and older adults did not differ in the percentages of their responses that were neutral, positive, or negative \((p > .1; \text{see Figure 3})\). Looking within the groups, the young adults recalled significantly more words used to generate positive versus neutral sentences \((p < .05)\), and marginally more words used to
generate negative versus neutral sentences \((p < .07;\) see Figure 3). They showed no difference in the percentage of recalled responses that were words used to generate positive versus negative sentences \((p > .1)\). The older adults, however, did not differ in the percentage of their responses that were words used to generate negative, positive, or neutral sentences \((p > .3;\) see Figure 3). ANOVAs showed no effect of group \((p > .15)\), an effect of item type \(\text{positive}, \text{negative}, \text{neutral}; p < .05\), and a marginal Group \(\times\) Item Type interaction \((p < .10)\). When positive and negative stimuli were combined into an emotional item category, ANOVAs indicated no effect of group \((p > .5)\), a significant effect of item type \((p < .01)\), and a significant Group \(\times\) Item Type interaction \((p < .05;\) see Figure 3).

These results indicate that young adults, but not older adults, showed better memory for neutral words used in an emotional context than in a neutral context.

**Older Adults and AD Patients**

Scores based on independent ratings of sentence contexts. When analyses were conducted on the percentage correct for words used in sentences rated as neutral, somewhat positive, highly positive, somewhat negative, or highly negative, ANOVAs indicated a significant effect of group \((p < .001)\), no effect of context type \((p > .8)\), and no Group \(\times\) Context Type interaction \((p > .8)\). The results were the same when only words used to generate sentences as neutral, highly positive, or highly negative were included in the analyses. Overall, older adults recalled significantly more words than the AD patients \((p < .001)\).
and they recalled more words from each context type than the AD patients (see Table 4).

Scores based on subjective sentence contexts. When the data were analyzed using the percentage of recall responses given to words that participants were instructed to use in neutral, positive, or negative sentences, ANOVAs indicated no effect of group (p > .15), no effect of item type (p > .15), and no Group x Item Type interaction (p > .15). When positive and negative items were combined into an emotional item category, ANOVAs showed no effect of group (p > .15), and no effect of item type or Group x Item Type interaction (p > .15). The two groups showed an equal percentage of recalled responses that were neutral (p > .15), positive (p > .15), and negative (p > .15; see Figure 3).

These results indicate no difference between the older adults and AD patients: Neither group benefited from the context in which a word occurred. These results further suggest that the AD groups' inability to benefit from emotional context is not due to deficits in the production of emotional contexts. The AD group did generate sentences rated as highly positive or highly negative, but they did not show better memory for the words used to generate these sentences than for words used to generate sentences rated as neutral.

Recognition Memory for Emotional Versus Neutral Stimuli, and for Neutral Stimuli Embedded in an Emotional Context

Young and Older Adults

The young and older adults did not differ in the number of negative or neutral words recognized (p > .3; see Table 5). Both groups recognized significantly more negative than neutral words (p < .0001). ANOVAs indicated no effect of group (p > .3), an effect of item type (negative, neutral; p < .0001), and no Group x Item Type interaction.

The groups also did not differ in the number of negative context or neutral context words recognized (p > .15). The young adults, however, recognized significantly more neutral words embedded in a negative versus neutral context (p < .01), whereas the older adults recognized an equal number of neutral words embedded in a negative or neutral context (p > .15). ANOVAs indicated no effect of group (p > .7), an effect of item type (p < .05), and a significant Group x Item Type interaction (p < .05; see Table 5).

These results indicate that normal aging did not affect the total number of words recognized or the memory benefit for emotional versus negative words. Older adults, however, did not benefit from the context in which a neutral word was embedded, whereas young adults showed better memory for words in an emotional versus a neutral context.

Older Adults and AD Patients

Overall, older adults recognized significantly more neutral and negative words than AD patients (p < .0001; see Table 5). ANOVAs indicated an effect of group (p < .0001), an effect of item type (p < .0001), and a Group x Item Type interaction (p < .05). Older adults recognized significantly more negative than neutral words (p < .05), whereas AD patients recognized an equal number of negative and neutral words (p > .15; see Figure 4). These results indicate that in AD, there is a reduction in the overall number of items recognized as well as loss of the memory benefit for emotional versus neutral items.

Older adults also recognized more neutral words embedded in a neutral context (p < .005), and a marginally greater number of neutral words embedded in a negative context (p < .10) than the AD patients (Table 5). ANOVAs showed an effect of group (p < .0001), no effect of item type (p > .15), and no Group x Item Type interaction (p > .15; see Figure 4). Thus, neither older adults nor AD patients showed improved memory for neutral items embedded in an emotional versus a neutral context.

Table 5

<table>
<thead>
<tr>
<th>Sentence Recognition: Mean Percentage Recognized (1 SD) for Negative and Neutral Words, and Neutral Words Embedded in a Negative or Neutral Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Young adults</td>
</tr>
<tr>
<td>Older adults</td>
</tr>
<tr>
<td>AD patients</td>
</tr>
</tbody>
</table>
Figure 4. Examples of correlations between source memory and emotional versus neutral context recognition: Older adults showed significant correlations between (a) attribution of a fact to the correct person and superior recall for neutral words in a positive versus a neutral context \(r = .69, p < .001\) and (b) attribution of a fact to an experiment and recognition enhancement for neutral items embedded in an emotional versus a neutral context \(r = .54, p < .05\).

**Correlation Between Memory for Neutral Stimuli Embedded in an Emotional Versus Neutral Context and Performance on Source Memory Tasks**

The older adults' performance on tests of source memory correlated positively with the memory benefit that they showed for neutral words embedded in an emotional versus a neutral context: Those older adults who performed best on the source memory tasks also showed improved memory for neutral words embedded in an emotional (positive or negative) context, whereas those who performed poorly on the source memory tasks showed no difference in memory for words embedded in an emotional or neutral context (see Figure 4). The correlations were not due to general correlations in memory performance (i.e., fact recall), because performance on the source memory tasks did not correlate with recall of emotional versus neutral items (see Table 6).

**Discussion**

The present study investigated whether normal aging and mild AD affected emotional memory. The
Table 6  
Performance on Source Memory Tasks Correlated Significantly With Measures of Enhanced Memory for Neutral Items in an Emotional Versus a Neutral Context (Bold Font) but not With Measures of Enhanced Memory for Emotional Versus Neutral Items

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measures of source memory</th>
<th>Measures of fact memory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source</td>
<td>Source</td>
</tr>
<tr>
<td></td>
<td>experiment</td>
<td>color</td>
</tr>
<tr>
<td>Emotional vs. neutral word-context recall</td>
<td>0.61</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>0.005</td>
<td>0.002</td>
</tr>
<tr>
<td>Positive vs. neutral word-context recall</td>
<td>0.64</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Negative vs. neutral word-context recall</td>
<td>0.47</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>0.038</td>
<td>0.020</td>
</tr>
<tr>
<td>Emotional vs. neutral context recognition</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Positive vs. neutral-word recall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emotional vs. neutral-sentence recognition</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive vs. neutral-picture-recall</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.017</td>
<td></td>
</tr>
</tbody>
</table>

The answer is affirmative: Older adults and AD patients showed reduced memory enhancement based on emotion. Their deficits, however, were dissociable. The AD group showed no memory enhancement on any task, whereas the older adults showed memory enhancement for emotional items but not for neutral items embedded in an emotional context. Neither older adults nor AD patients showed any impairment at rating the stimuli as positive, negative, or neutral, consistent with other studies that have found preserved emotional perception in normal aging and AD (Hamann et al., 2000).

First, focusing on the comparison between the older adults and AD patients, this study suggests that mild AD affects emotional memory, such that AD patients do not show better memory for emotional compared with neutral items. We found only weak evidence that AD disproportionately affects memory for negative compared with positive stimuli: On the word-recall test, AD patients showed a trend toward recalling more positive than negative words, consistent with Hamann et al.’s (2000) finding of relatively preserved memory enhancement for positive stimuli in AD. This trend was not significant, however, and it was absent from all other administered tests. This experiment, therefore, suggests that memory enhancement for negative and positive stimuli is not present in mild AD. This result provides support for the hypothesis that the amygdala is used to boost memory for positive as well as negative stimuli, such that AD patients, who are known to have severe atrophy of the amygdala (Krasuski et al., 1998; Mizuno et al., 2000; Scott, 1993; Scott et al., 1991; Scott, DeKosky, Sparks, Knox, & Scheff, 1992; Vogt et al., 1990), do not show the memory advantage for either category of stimuli. It cannot be ruled out, however, that the deficits result from pathologies in other brain regions.

The literature to date has been mixed with regard to whether AD patients show impaired (Hamann et al., 2000) or preserved (Kazui et al., 2000; Moayeri et al., 2000) emotional-memory enhancement effects. It is unclear what differences in methodologies may account for the different conclusions. One possibility is that AD patients show normal enhancement effects for stimuli based on valence differences, but impaired enhancement based on differences in stimulus arousal level (see Phelps et al., 1998, for distinct effects of valence and arousal). Our investigation, however, did
not provide evidence for this hypothesis. The picture-recall test allowed us to analyze effects of valence and arousal separately; we found that AD patients did not show a consistent memory enhancement for pictures based on either valence or arousal differences. It may be that the type of stimuli, or the richness of the information available (e.g., multiple modalities, semantic elaboration), determines whether the AD group shows an emotion enhancement effect. To date, the studies that have found normal emotional memory enhancement effects in AD patients have looked at real-life emotional events (Ikeda et al., 1998) or stories (Kazui et al., 2000; Moayeri et al., 2000). The present study, like the other study (Hamann et al., 2000) that used pictures (no prior study had used word lists or sentences), found impaired enhancement. Future investigations should focus on clarifying when AD patients are spared versus impaired at emotional memory, and whether differences in arousal and valence combinations, encoding instructions, or retrieval instructions, modulate the effect. Regardless of the exact nature of the effect, however, the results reported here suggest that the lesions to the amygdala in AD are sufficient to disrupt the emotional-memory enhancement effect: Complete ablation of the amygdala is not necessary to disrupt the effect.

The second goal of this study was to examine whether normal aging affects emotional memory. The results suggest that memory for emotional stimuli continues to be better than memory for neutral stimuli in older adults, and that the amount of benefit for emotional versus neutral stimuli does not change with normal aging. In other words, not only did young and older adults benefit from the emotional valence of the stimuli, they also benefited to a similar degree. Apparently, the modest amygdaloid atrophy that occurs with normal aging is not sufficient to disrupt the emotional-memory enhancement effect. In addition to providing useful knowledge for our understanding of emotional memory, the dissociation between the older adults and patients with mild AD also may be clinically important. For example, including tests of emotional memory enhancement as part of the neuropsychological assessment could help to distinguish AD from normal aging.

The third goal of this study was to ask whether memory enhancement for neutral stimuli embedded in an emotional context resulted from the function of neutral substrates beyond those that support memory enhancement for emotional items. Our results suggest that the two enhancement effects can be dissociated: In contrast to older adults’ preserved memory enhancement for emotional compared with neutral stimuli, they showed no memory benefit for neutral stimuli embedded in an emotional context. The fact that normal aging predominantly affects the structure and function of the frontal cortex suggests that frontal lobe regions may be critical for the context enhancement effect. The significant correlations between contextual enhancement and performance on source memory tasks further implicate frontal lobe capacities in the phenomenon. The same frontal lobe region may support the two types of memory. Source memory is believed to rely on the dorsolateral prefrontal cortex (Johnson, Kounios, & Nolde, 1997); this region may also be important for the ability to link a neutral item to its emotional context. It is also possible, however, that different areas within the frontal lobe support the two effects, and that individuals with atrophy to frontal regions critical for source memory also have atrophy in regions required for the contextual enhancement effect. For example, orbitofrontal cortex, with its rich connections with the amygdala (see Barbas, 2000, for review), may be more important for the emotional context enhancement effect, whereas more lateral frontal regions may be responsible for source memory performance. The hippocampal formation, which has reciprocal connections with the amygdala, could also be important for binding features together at encoding (Mitchell, Johnson, Raye, & D’Esposito, 2000). The one functional magnetic resonance imaging study that has addressed this question suggests that the dorsolateral prefrontal cortex may be particularly important for the context enhancement effect. Maratos et al. (2001) found that when individuals retrieved words learned in a negative versus neutral context, activation was greater in right dorsolateral prefrontal cortex, as well as in limbic regions typically associated with memory for emotional items (e.g., amygdala, posterior cingulate gyrus).

In conclusion, the results of this experiment support a dissociation between enhanced memory effects for emotional stimuli and for neutral stimuli in an emotional context. Normal aging affects only the latter, suggesting a role of frontal lobe capacities. AD, however, affects both types of memory enhancement. This disruption of emotional memory in AD likely results from atrophy to limbic structures and appears to affect memory for positive and negative stimuli.

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