REMEMBERING EMOTIONAL INFORMATION:
EFFECTS OF AGING AND ALZHEIMER’S DISEASE

Elizabeth A. Kensinger¹,²,*
¹Department of Psychology, Harvard University
²The Athinoula A. Martinos Center for Biomedical Imaging

ABSTRACT

Many events that we experience are of personal relevance and contain rich, emotional meaning. For young adults, these events are more likely to be remembered than events lacking emotional importance, and the emotional events also are more likely to be recalled in vivid detail. These effects of emotion on memory have been termed emotional memory enhancement. Recent studies have begun to examine whether these memory enhancement effects remain intact across the adult lifespan and in patients with Alzheimer’s disease. This chapter will review evidence that healthy aging leaves intact many of the effects of emotion on memory, whereas Alzheimer’s disease often disrupts the memory benefit elicited by emotional content. Across a range of implicit and explicit memory tasks, patients with Alzheimer’s disease have failed to demonstrate a memory boost for emotional compared to nonemotional information. The lack of memory enhancement does not appear to stem from deficits in the ability to process emotional information or to recognize emotional meaning: Patients with Alzheimer’s disease often perform normally on tasks assessing emotional processing. Rather, the diminution of emotional memory enhancement in Alzheimer’s disease probably reflects a disruption in the modulation of encoding and consolidation processes typically elicited by emotion. At a neural level, the blunted emotional memory enhancement in Alzheimer’s disease likely results from the atrophy and dysfunction that occurs in limbic regions, including the amygdala.

Keywords: affect, aging, Alzheimer’s disease, amygdala, emotion, memory.
INTRODUCTION

We often are confronted with information that elicits an emotional response. This emotional information is typically more likely to be remembered than nonemotional information. An extreme example of this emotional memory enhancement occurs in instances of “flashbulb memories” (Brown & Kulik, 1977), when individuals form a memory of an arousing and surprising event that feels incredibly vivid and detailed. Even in laboratory settings, researchers have demonstrated that the emotional content of items can modulate the subjective vividness associated with a memory. For both pictures (Ochsner, 2000; Heuer & Reisburg, 1990) and words (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Kensinger & Schacter, in press; Kensinger, Garoff-Eaton, & Schacter, 2006), individuals are more likely to indicate that they can remember specific details associated with an item’s presentation if it is negative than if it is neutral.

NEURAL PROCESSES SUPPORTING EMOTIONAL MEMORY ENHANCEMENT

Neuroimaging studies, and studies of patients with focal brain lesions, have converged on the conclusion that the amygdala is critical for the emotional memory enhancement (reviewed by Hamann, 2001; Kensinger, 2004; Kensinger, in press; Phelps, 2004). In healthy adults, the amount of activity in the amygdala (typically quantified through measurement of blood oxygenation level-dependent signal in functional magnetic resonance imaging) during the processing of emotional information corresponds with the likelihood that emotional items will later be remembered. This effect has been demonstrated with pictures (e.g., Canli et al., 2000; Dolcos, LaBar, & Cabeza, 2004) and words (e.g., Kensinger & Corkin, 2004b). Moreover, activity in the amygdala and other limbic regions (e.g., orbitofrontal cortex) corresponds with the likelihood that emotional information will be remembered accurately, versus in a distorted fashion (Kensinger & Schacter, 2005a; Kensinger & Schacter, 2005b). Patient studies have confirmed that the amygdala plays a necessary role in the memory enhancement for emotional information. Patients with damage to the amygdala do not show a memory benefit for emotional information: They are no more likely to remember positive or negative information than they are to remember neutral information (e.g., Adolphs, Cahill, Schul, & Babinsky, 1997; Adolphs, Tranel, & Denburg, 2000; Brierley, Medford, Shaw, & David, 2004; Markowitsch et al., 1994).

The amygdala likely exerts its influence via modulation of other MTL structures (reviewed by Phelps, 2004). A few neuroimaging studies have found correlations between the activity in the amygdala and in the hippocampus during the encoding of emotional information (Dolcos et al., 2004; Kensinger & Corkin, 2004b; Kensinger & Schacter, 2005a). Moreover, in patients with atrophy to the amygdala, there is an inverse correlation between the amount of amygdalar atrophy and the level of activity in the hippocampus during the processing of emotional information (Richardson, Strange, & Dolan, 2004). However, normal functioning of these other MTL structures does not appear necessary for the emotional memory enhancements to occur: Amnesic patients with severe MTL damage show a memory benefit for emotional as compared to neutral stimuli (Hamann, Cahill, McGaugh, & Squire, 1997; Hamann, Cahill, & Squire, 1997). Thus, the amygdala appears to be the MTL region critical for emotion-induced memory enhancement. Of course, the role of the amygdala does not negate potential contributions of other brain regions, and indeed, patient and neuroimaging studies have suggested that the declarative memory enhancement
for emotional information may also rely on the orbitofrontal cortex and cingulate gyrus (Cahill et al., 1995; Maddock, Garrett, & Buonocore, 2003; Phelps, LaBar, & Spencer, 1997; Kensinger & Schacter, 2005a; Kensinger & Schacter, 2005b).

**Emotional Memory Across the Adult Lifespan**

In comparison to the large body of literature examining emotional memory in young adults (typically college-age students), relatively few studies have examined the extent to which emotional memory changes across the adult lifespan. It is known that healthy aging results in alterations in memory; of particular relevance, older adults often show decrements in the ability to remember information in vivid detail or with contextual associations (e.g., Craik & McDowd, 1987, Mantyla, 1993, Rugg & Morcom, 2005; Spencer & Raz, 1995). It has therefore been of interest to examine whether the emotional salience of information enhances the likelihood that older adults vividly remember information, or whether this memory-enhancing effect of emotion is limited to young adults.

The majority of studies examining this issue have assessed “flashbulb memories” of emotionally salient (usually negative) public events. These studies have come to mixed conclusions regarding the effect of aging on the vividness of emotional memories. Some studies have suggested that age does not have a detrimental effect on the likelihood of retaining vivid memories of an emotional event (e.g., for the assassination of J.F.K.; Christianson, 1989; for the resignation of Margaret Thatcher; Wright, Gaskell, & O'Muircheartaigh, 1998). Other investigations, however, have demonstrated that age does correlate negatively with the likelihood of retaining details of an emotional event (e.g., for the assassination of J.F.K.; Yarmey & Bull, 1978; for the resignation of Margaret Thatcher; Cohen, Conway & Maylor, 1994; for the death of the 8th president of Turkey, Tekcan & Peynircioglu, 2002).

A limitation of these studies is that they did not include a nonemotional control event. Thus, it is difficult to tease apart the general effects of age on memory from those specifically related to the emotional salience of an event. In other words, the reduced ability for older adults to vividly remember information could either reflect a general deficit in vividly remembering any type of information (emotional or nonemotional) or a specific difficulty vividly remembering events with emotional content. A nonemotional control condition is essential to distinguish these possibilities. A study by Davidson & Glisky (2002) did include such a control condition, asking young and older adults about the deaths of Princess Diana and Mother Theresa, and about a nonemotional control event that occurred on Labor Day weekend. They found that young and older adults recalled more information about the emotional events (the deaths) than about the nonemotional control event. Moreover, age had no effect on the frequency with which flashbulb memories were formed. Similar conclusions were drawn in a recent study examining memory for a highly emotional event (the Columbia shuttle explosion) and a less emotional event (the Super Bowl): Although older adults had poorer memory than the young adults, both age groups remembered more about the shuttle than about the Super Bowl, and the age discrepancy in memory was less pronounced for the emotional event (Kensinger, Krendl, & Corkin, 2006). Thus, this couple of studies suggests that although older adults remember information less vividly than young adults, they nevertheless show a memory benefit for emotional as compared to nonemotional events.
While these “flashbulb memories” provide a window through which one can examine memory for highly arousing events, such events occur only rarely, and even when they do occur, it is often difficult to assess memory for a control event temporally proximate to the event. Thus, researchers recently have begun to use laboratory investigations to examine the effects of emotion on memory in young and older adults. The majority of these studies have found that the emotional memory advantage seen in young adults is maintained, or even enhanced, in older adults (Carstensen & Turk-Charles, 1994; Denburg et al., 2004; Hashtroudi, Johnson, & Chrosniak, 1990; Kensinger, Anderson, Growdon, & Corkin, 2004; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Kensinger & Corkin, 2004a; Kensinger, Piguet, Krendl, & Corkin, 2005; Leigland, Schultz, & Janowsky, 2004; Mather, 2004; Rahhal, May & Hasher, 2002). In the vast majority of these studies, young and older adults have been asked to study, and later to recall, words or pictures that are positive, negative, or neutral. The most consistent finding has been that older adults, like young adults, show a memory boost for the positive as compared to the neutral information. A few studies have suggested that older adults may show a disproportionate memory advantage for positive stimuli compared with negative stimuli (Charles, Mather, & Carstensen, 2003; Leigland et al., 2004), perhaps due to motivational changes across the lifespan. Older adults may be more likely to focus on positive information encountered in everyday life, and less likely to attend to negative information (e.g., Carstensen, Fung, & Charles, 2003). However, a number of studies have shown that older adults show a normal memory advantage for negative stimuli as well (Denburg et al., 2004; Kensinger et al., 2002; Kensinger et al., 2004; Kensinger et al., 2005; Kensinger & Corkin, 2004a)

The fact that older adults often do show normal enhancement for emotional information is consistent with the neural evidence indicating that the amygdala and other limbic regions (e.g., orbitofrontal cortex) are relatively spared in healthy aging. For example, the amygdala shows minimal atrophy with healthy aging; the volumetric decline in the amygdala is on par with the decline in whole-brain volume (e.g., Coffey et al., 1992; Good et al., 2001; Raz et al., 1997; Tisserand, Visser, van Boxtel, & Jolles, 2000). Similarly, orbitofrontal cortex may be relatively spared in comparison to other regions of the prefrontal cortex (Salat, Kaye, & Janowsky, 2001). Thus, it is likely that the circuitry underlying the emotional memory enhancement is relatively preserved across the adult lifespan.

**NEUROANATOMICAL CHANGES IN ALZHEIMER’S DISEASE**

Although multiple brain abnormalities accompany Alzheimer’s disease, the diagnosis requires identification (at autopsy) of an abundance of extracellular neuritic plaques and intracellular neurofibrillary tangles. Although these cellular abnormalities are often apparent throughout the brain by the time the disease has progressed to its later stages, the medial temporal-lobe regions are typically those most affected. Even early in the disease, the hippocampal formation shows marked atrophy (e.g., Dickerson et al., 2001; Du et al., 2001; reviewed by Kensinger & Corkin, 2003) and atrophy in the entorhinal cortex serves as one of the best predictors for development of Alzheimer’s disease (de Toledo-Morrell et al., 2000).

Not surprisingly, given the role of the medial temporal-lobes in acquiring novel episodic information (reviewed by Squire, Stark, & Clark, 2004), Alzheimer’s disease patients are best identified by their difficulties remembering recently learned information (Locascio, Growdon, & Corkin, 1995). While the vast majority of studies have assessed the memories of Alzheimer’s
disease patients using standard assessments of memory for nonemotional information, a question of recent interest has been the extent to which Alzheimer’s Disease patients benefit from the emotional nature of information.

In contrast to healthy aging, which leaves the amygdala relatively intact, Alzheimer’s disease results in marked changes in the amygdala, even relatively early in the disease (Chow & Cummings, 2000; Krasuski et al., 1998; Mizuno et al., 2000). Estimates of volumetric reductions range anywhere from 20% to 50% (Chan et al., 2001; Galton et al., 2001; Jack et al., 1999; Scott, 1993; Scott, DeKosky, & Scheff, 1991; Scott et al., 1992; Smith et al., 1999), and microscopically, neuritic (amyloid) plaques and neurofibrillary tangles are abundant in the amygdala (Arriagada et al., 1992; Unger et al., 1991; Vogt et al., 1990) as well as in the other medial temporal-lobe regions. Studies have recently begun to examine whether these changes in the limbic system are sufficient to disrupt the memory enhancement for emotional information.

**EMOTIONAL MEMORY IN ALZHEIMER’S DISEASE**

The bulk of the evidence from the laboratory points to disruptions in the emotional memory enhancement effect, even in relatively mild cases of Alzheimer’s disease. For example, Kensinger et al. (2002) asked young adults, older adults, and patients with mild Alzheimer’s disease to study a series of photographs. Some pictures were positive, others were negative, and others were neutral. After viewing the photographs, participants wrote down descriptions of all the ones they remembered. While the young and older adults recalled more negative or positive pictures than neutral pictures, the Alzheimer’s disease patients showed no such memory boost for the emotional pictures. As expected, their overall recall rates were lower than those of the older adults, but they also were no more likely to recall a positive or a negative picture than they were to recall a neutral picture. This blunted emotional memory enhancement effect in Alzheimer’s disease patients has now been demonstrated in a number of studies comparing memory for negative, positive, and neutral pictures, words, and sentences (Abrisqueta-Gomez, Bueno, Oliveira, & Bertolucci, 2002; Kensinger et al., 2002; Kensinger et al., 2004). Furthermore, this blunted emotional memory enhancement is not merely a side-effect of the low memory performance of the Alzheimer’s disease patients. Even when the overall memory levels of the healthy older adults and Alzheimer’s disease patients are equated, there is an interaction between group and emotion: Older adults show a memory benefit for emotional information, whereas Alzheimer’s disease patients do not (Kensinger et al., 2004).

In addition to these changes in emotionally influenced declarative memory, Alzheimer’s disease patients have also demonstrated impairments in emotionally mediated implicit memory. For example, they have difficulties learning that a particular stimulus predicts an aversive event in a fear conditioning paradigm (Hamann, Monarch, & Goldstein, 2002), and they do not show normal affective priming for positive stimuli (Padovan, Versace, Thomas-Anterion, & Laurent, 2002). Taken together, these results suggest that the emotional memory deficits in Alzheimer’s disease are not limited to the domain of explicit memory, but may occur anytime that the amygdala is critical for the modulation of memory by emotion.

Despite this evidence of impaired emotional memory modulation in Alzheimer’s disease, however, there are a few laboratory studies demonstrating relatively intact emotional memory enhancement in Alzheimer’s disease. These studies have investigated memory for negative stories and film clips, and the critical finding has been that the patients with Alzheimer’s disease showed
better memory for the emotional information than for the neutral information (Boller et al., 2002; Kazui et al., 2000; Kazui, Mori, Hashimoto, & Hirono, 2003; Moayeri, Cahill, Jin, & Potkin, 2000). In one of these studies, ceiling effects in the control group prevented comparison of the magnitude of the enhancement in the two groups (Moayeri et al., 2000), but in the other studies, the magnitude of the enhancement effect also appeared comparable in the Alzheimer’s disease patients and in their age-matched control participants.

There are also a couple of studies of real-life events suggesting that, while Alzheimer’s disease patients may not show normal memory for emotional events, emotion can nevertheless enhance memory retention. For example, Ikeda et al (1998) found that Alzheimer’s disease patients were much more likely to remember the Kobe earthquake than they were to remember an MRI scan that had taken place around the same time as the earthquake. In a more recent study of memory for the terrorist attacks on September 11th, 2001, patients with Alzheimer’s disease were found to retain more personal than factual information about the event (Budson et al., 2004). Although this same pattern of results was also shown in the older adults (see also Larsen & Thompson, 1995), the pattern was exaggerated in the Alzheimer’s disease group. These results suggest that the arousing nature of real-life events can modulate memory in patients with Alzheimer’s disease. Moreover, it appears that amygdalar volume predicts the extent of such modulation. Mori and colleagues (1999) found that amygdalar volume strongly correlated with the likelihood that patients would remember personal information about the Kobe earthquake, consistent with current proposals regarding the amygdala’s role in emotional memory (reviewed by McGaugh, Cahill, & Roozendaal, 1996; Phelps, 2004).

Thus, the data are somewhat mixed with regard to the effects of Alzheimer’s disease on emotional memory. The general conclusion to emerge from seems to be that, with extreme levels of arousal (as with the Kobe earthquake or the 9-11 terrorist attacks), Alzheimer’s disease patients do show a memory boost for emotional information. Nevertheless, in most circumstances, the memory boost for emotional information is disrupted in Alzheimer’s disease. It is likely that the amygdala atrophy that occurs with Alzheimer’s disease is sufficient to reduce the emotional memory enhancement effect. Further studies will be needed to elucidate the extent to which patient characteristics (e.g., disease stage), stimulus features (e.g., arousal level; valence; personal relevance), or memory demands (e.g., requirement for retrieval of detailed event information; delay interval) modulate the strength of the emotional memory enhancement in patients with Alzheimer’s disease.

**Emotional Processing in Alzheimer’s Disease**

One concern has been whether these findings are specific to emotional memory, or whether they relate more generally to changes in emotional processing with Alzheimer’s disease. If an individual did not have an emotional reaction to an event, or did not recognize its emotional importance, it would not be surprising to find that the person would not have enhanced memory for that event. Thus, it is plausible that the reduced emotion-induced memory boosts in Alzheimer’s disease stem from deficits in responding to emotional events.

Most studies, however, have found that Alzheimer’s disease patients are normal at rating stimuli as positive, negative, or neutral, even when they do not show a corresponding memory benefit for the positive and negative items (e.g., Abrisqueta-Gomez et al., 2002; Kensinger et al., 2002; Kensinger et al., 2004). For example, Abrisqueta-Gomez and colleagues (2002) and Kensinger and colleagues (2002) found that Alzheimer’s disease patients classified the same
pictures as positive or negative as did healthy older adults. In another study, Kensinger and colleagues (2004) found that Alzheimer’s disease patients gave valence and arousal ratings for sentences that were comparable to those given by healthy older adults. In addition to this preservation in emotional ratings, skin conductance responses also appear normal in patients with Alzheimer’s disease (Hamann et al., 2000). These data suggest that, at least in the laboratory, responses to emotional stimuli are often intact in patients with Alzheimer’s disease. Further evidence of relatively preserved emotional processing in Alzheimer’s disease came from an investigation of emotional reactions to the terrorist attacks on September 11th 2001: Budson and colleagues (2004) found that Alzheimer’s disease patients reported similar intensities of six emotions (sadness, anger, fear, confusion, frustration, shock) as did healthy older adults.

There are a few studies suggesting that patients with Alzheimer’s disease show impairments in processing emotional stimuli (Albert, Cohen, & Koff, 1991; Allender & Kaszniak, 1989; Bros gol e, Kurucz, Plahovinsak, & Gumiela, 1981; Cadieux & Greve, 1997). However, in many of these studies, it is likely that the patients’ emotional impairment was secondary to perceptual or cognitive difficulties (Albert et al., 1991; Bros gol e et al., 1981; Burnham & Hogervorst, 2004; Cadieux & Greve, 1997). Indeed, on tasks with relatively low perceptual requirements, Alzheimer’s disease patients were capable of recognizing emotion from nonverbal sources, including facial expressions (Bucks & Radford, 2004; Burnham & Hogervorst, 2004; Shimokawa et al., 2003) and vocal prosody (Bucks & Radford, 2004). Thus, although there are changes in the limbic system with Alzheimer’s disease, these changes do not appear to dramatically affect the ability to detect emotion or to experience emotion.

**CONCLUSIONS**

Deficits in the formation of new episodic memories are the hallmark of Alzheimer’s disease. Although numerous studies have investigated these declarative memory deficits, recent attention has been drawn to the modulatory effects of emotion on memory and the extent to which this modulation is disrupted with healthy aging and Alzheimer’s disease. Studies to date have suggested that healthy aging leaves the emotional memory enhancement effect relatively intact. In contrast, while Alzheimer’s disease patients remain capable of processing emotional information and responding to emotional events, they do not show the same memory boost for emotional information as demonstrated by healthy older adults. The contrast between the performance of healthy older adults and Alzheimer’s disease patients likely results from the significant changes to limbic regions, including the amygdala, that accompany Alzheimer’s disease.

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