

## CHAPTER 2: THEORETICAL BACKGROUND

The Theoretical Background focuses on the interplay between aging, memory, and emotion. In the first part, I review naturalistic (see section 2.1) and experimental studies (see section 2.2) that investigate age-related differences in remembering emotionally-toned material or events. The review focuses on experimental studies which investigate age-related differences in the positive-negative disparity of emotional memory. It highlights information relevant for a systematic investigation of age-related differences in memory for emotionally-toned material. The review concludes with a discussion of potential reasons for inconsistent findings with regard to age-related differences in the positive-negative disparity.

In the third part (see section 2.3), potential mechanisms are discussed that are related to the general enhancement of memory by emotion and to the specific positive-negative disparity of emotional memory. These mechanisms, such as attention, arousal, emotion regulation, long-term consolidation, and mood-congruency effects, are discussed in terms of their association to age-related differences in memory for emotionally-toned material.

### 2.1 AGE-RELATED DIFFERENCES IN EMOTIONAL MEMORY: EMPIRICAL FINDINGS FROM NATURALISTIC APPROACHES

The naturalistic approach to investigate memory for emotional events is primarily associated with research on naturally-occurring events which have significant consequences for political and social life. Researchers ask participants about their memories of these events (so-called flashbulb memories) or memories of personal autobiographical events (see section 1.2.1 *Naturalistic Approaches to Investigate Emotional Memory*). The majority of studies on memory for naturally-occurring emotional events have been done with young adults. There are, however, a few studies investigating age-related differences in memory for neutral and emotional events.

#### 2.1.1 Memory for Neutral versus Emotional Events

Two studies investigated memory vividness and memory clarity for naturally-occurring emotional events using different age groups. In a large representative survey in Great Britain (Wright, Gaskell, and O’Muircheartaigh, 1998), participants were asked about their memory for Margaret Thatcher’s resignation as prime minister and the Hillsborough stadium disaster in which 96 people were crushed to death. Nineteen months after the

resignation of Margaret Thatcher and 36 months after the football tragedy, self-ratings for memory clarity increased with participants' age until age 75. Thus, older adults reported greater memory clarity for both emotional events. In a similar study, Yarmey and Bull (1978) asked participants twelve years after the assassination of President Kennedy about the circumstances under which they heard about the assassination. In contrast to the findings by Wright and colleagues, Yarmey and Bull found less detailed and vivid descriptions of the surrounding circumstances in people older than 66. Regardless of the inconsistent findings for memory clarity and vividness, both studies did not include objective measures of memory accuracy. As mentioned above (see section 1.2.1), highly vivid memories can be completely out of step with the historical facts.

Two additional studies investigated age-related differences in the accuracy of recalling an emotional event. In these studies, recall was measured within a few weeks of the event and again several months later. G. Cohen, Conway, and Maylor (1994) found that older adults were less able than young adults to form flashbulb memories related to the resignation of the British Prime Minister Margaret Thatcher: Whereas 90% of young adults were able to generate flashbulb memories, only 42% of older adults were able to do so. The authors concluded that the inability of the majority of the older adults to form flashbulb memories was attributable to deficits in their memory for source and context.

P. S. R. Davidson and Glisky (2002) investigated the idea that the formation of flashbulb memories in older adults is related to executive functioning. To do this, they examined memory details for the deaths of Princess Diana and Mother Teresa in 53 healthy older adults. The sample was divided in 29 older adults ( $M = 74.0$ ) with high executive functioning and 24 older adults ( $M = 72.4$ ) with low executive functioning. In addition, 19 young adults ( $M = 19.9$ , aged 18 to 32) from undergraduate introductory psychology classes were used as a control group. The authors expected to find less accurate memory for details in older adults with low executive functioning than in older adults with high executive functioning. Contrary to expectations, executive functioning was not related to accuracy for flashbulb memories in older adults. This finding is relevant for resource-based accounts of age-related differences in remembering emotionally-toned material signifying that executive functioning is not necessarily involved in the formation of accurate recollections of emotional events. In contrast to Cohen and colleagues, the findings by Davidson and Glisky did not find significant differences in memory accuracy between the entire group of older adults and the group of young adults. There was, however, a trend that young adults show more accurate memory than older adults. Davidson and Glisky acknowledge that the small sample size of

young participants may have limited the possibility to find significant age differences. Thus, both studies show a trend for an age-related decline in the accuracy of recalling the circumstances under which participants were told about the emotional events. One explanation for this finding might be that the emotional information of an event actually interferes with the memory formation for this event by grabbing processing resources. The reduction of processing resources by emotion might be most relevant for older adults who already hold less processing resources than young adults (e.g., Salthouse, 1991).

Additional evidence for the idea that emotion might interfere with memory accuracy in older adults is provided by two studies which investigated the influence of an affective (i.e., emotional) focus on non-affective material. In a study by Hashtroudi, Johnson, and Chrosniak (1990), young and older adults participated in scripted (i.e., perceived) and imagined situations (e.g., packing a picnic basket). After some intervening tasks, participants rated their memories on a memory characteristics questionnaire that assessed the amount of perceptual and contextual detail associated with the perceived and imagined situations. On the next day, participants were asked to give a detailed description of the perceived and imagined situations. On the self-report memory questionnaire, older adults indicated that they had better memory for thoughts and feelings than younger adults did. In their actual report of the events, older adults used indeed more thoughts and feelings to describe the events. Some authors argue (e.g., Carstensen & Turk-Charles, 1994; Mather, 2003) that the findings by Hashtroudi and colleagues are evidence that the salience of emotions increases with age. However, Hashtroudi and colleagues did not assess the accuracy of the recalled events making it rather difficult to evaluate the source of the reported and recalled thoughts and feelings. In fact, these thoughts and feelings are probably intrusions or inferences that are not automatically related to the recalled events.

Support for this idea was provided by a study that manipulated the focus of monitoring a play (Hashtroudie, Johnson, Vnek, Ferguson, 1994). In this study, young and older adults participated in a short play and were instructed to talk about factual or affective aspects of the play or to talk about the play without any particular focus suggested. Half of the participants performed a source-monitoring task for statements of the play. The analyses on the source-monitoring task showed an interaction between age and focus condition: Whereas young adults performance was unaffected by the focus condition, older adults were significantly less accurate in the affective and control condition. The other half of the participants recalled the play. Both young and older adults remembered less under the affective focus condition. Moreover, participants in the affective focus condition recalled

more inferences about and elaborations on the play than participants in both other conditions. Thus, the affective focus can lead to inferences about an event being confused with the event itself.

### **2.1.2 Memory for Positive versus Negative Events**

In a large survey, Berntsen and Rubin (2002) asked 1,242 participants (aged 20 to 93 years) for their age in their happiest, saddest, most traumatic, most important, and most recent involuntary memory. For happy memories, older adults tended to pick an event from their 20s. This results in an autobiographical bump for happy memories, namely that people remember information encountered during adolescents and early adulthood better than information encountered earlier or later in life (e.g., Rubin, Rahhal, & Poon, 1998). For sad or traumatic personal memories, older adults picked more recent events resulting in a monotonically decreasing retention function. To say it differently, the likelihood of recalling a sad or traumatic event decreases with longer retention intervals. One explanation for the reduced recall of remote sad and traumatic events might be reduced rehearsal of negative events during the life course. Reduced rehearsal of negative personal events across the life span might also explain one finding from a longitudinal study (Field, 1981). Sixty adults were asked four times across a 44-year period to rate the happiness of their childhood. The results revealed a clear significant and linear trend that participants rated their childhood as increasingly happier the older they became. In both studies (Berntsen & Rubin, 2002; Field, 1981), the retention interval is directly confounded with participants' age making it difficult to disentangle the contribution of age and retention interval in the linearly decreased recall of negative events.

There is, however, some evidence for age-related differences in recalling the emotional intensity of past events. After Ross Perot's abrupt withdrawal from the presidential race in 1992, Levine & Bluck (1997) asked political supporters of Ross Perot to rate their initial emotional reactions within one month after the withdrawal and again four months later. In the initial report of emotional reactions, no age differences were apparent. In the follow-up questionnaire four months later, among those participants who still wished that Perot had been elected, older adults remembered experiencing less intense sadness than young adults did. Thus, older adults remembered the intensity of their emotional reactions as less negative than young adults did. In a similar vein, Kennedy, Mather and Carstensen (2004) investigated long-term memory for personal information provided 14 years earlier. To do this, they interviewed 28 middle-aged nuns (aged 47 to 65) and 28 older nuns (aged 79 to 101) in 2001

who participated in a survey in 1987. The nuns got the original questionnaire from 1987 and were asked to “answer the questions as you think you answered them back then.” Older nuns remembered the past more positively than they originally reported in 1987, whereas middle-aged nuns remembered the past more negatively than originally reported. Both studies (Kennedy et al., 2004; Levine & Bluck, 1997) revealed an age-related decline in remembering the negative aspects of the autobiographical past.

### 2.1.3 Summary of Findings

The findings from studies using naturalistic approaches to investigate age-related differences in remembering emotionally-toned events are rather consistent. First, the findings suggest an age-related decline in the accuracy of recalling significant naturally-occurring events. Despite inconsistent findings by Wright and colleagues (1998) and Yarmey and Bull (1978) on age-related differences in memory clarity and memory vividness, G. Cohen and colleagues (1994) and P. S. R. Davidson and Glisky (2002) find a trend that young adults show more accurate memory for emotional events than older adults. However, both studies did not assess a neutral event making it difficult to interpret the source for this age-related decline.

There are at least two possible explanations for age-related differences in remembering emotional events: On the one hand, age-related differences might be related to a general decline in memory functioning. On the other hand, negative age differences might be related to specific changes in the extent to which memory can be enhanced by emotion. The findings by Hashtroudi and colleagues (1990, 1994) and by Davidson and Glisky point to the second explanation. Davidson and Glisky examined the impact of frontal lobe functioning (i.e., executive functioning) on memory for the emotional events. They found no evidence that executive functioning is related to the formation of flashbulb memories. Moreover, the studies by Hashtroudi and colleagues suggest that there is an age-related increase in the potential interference of affective information in remembering an event. However, more research is necessary to disentangle different explanations for age-related differences in remembering emotional events in naturalistic environments.

Regarding age differences in remembering positive and negative aspects of emotional events, a second consistent pattern emerged: Studies examining memory for positive and negative aspects are indicative of an age-related decline in remembering negative aspects of the autobiographical past. Berntsen and Rubin (2002) found a linear decline in remembering sad and traumatic personal events with increasing retention interval. Moreover, in a

longitudinal study (Field, 1981), participants rated their childhood as increasingly happier the older they became. Both studies suggest that negative events might undergo less rehearsal across the life course. The studies by Kennedy and colleagues (2004) and Levine and Bluck (1997) revealed that older adults remember the past as being much more positive than it originally was. Thus, older adults view the past through “positive lenses”. However, naturalistic approaches do not allow systematic control for the type of emotional event or for rehearsal and coping strategies. In this context, laboratory experiments might be helpful to disentangle possible explanations for a positive view of the past.

## **2.2 AGE-RELATED DIFFERENCES IN EMOTIONAL MEMORY: EMPIRICAL FINDINGS FROM EXPERIMENTAL APPROACHES**

Despite the fact that the topic of memory for emotionally-toned material has been repeatedly the focus of experimental investigations over the last 100 years (see section 1.2.2 *Experimental Approaches to Investigate Emotional Memory*), it is only in the last two decades that experiments were undertaken to examine age-related differences in memory for emotionally-toned material. The following sections review experiments that investigate age-related differences in memory for emotionally-toned material. This literature can be divided in two categories. In the first part, I review early studies which compared memory for neutral and emotionally-toned material. Although these studies do not provide information about the positive-negative disparity of emotional memory, they do inform about the generality of the enhancement effect of memory by emotion in older adults. In the second part, there are more recent studies that investigate age-related differences in memory for positively- and negatively-toned material.

Table 1 summarizes the studies reviewed including information about the type of memory task (e.g., free recall), the type of to-be-remembered material (e.g., words), and the retention interval used (e.g., 10 minutes). In addition, Table 1 gives information about the findings in comparing memory performance for positive, negative, and neutral material in young and older adults.<sup>3</sup> For all three possible comparisons in memory performance, negative versus positive material (N-P), negative versus neutral material (N-O), and positive versus neutral material (P-O), the direction of the effect is presented. Thus, Table 1 indicates whether young and older adults showed no difference in memory performance between

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<sup>3</sup> To facilitate Table 1, the groups of middle-aged participants (Charles et al., 2003; Denburg et al., 2003; Yoder & Elias, 1987) and Alzheimer’s disease patients (Kazui et al., 2000; Kensinger et al., 2002) were omitted.

Table 1  
*Summary of Findings for Age Differences in Remembering Emotionally-Toned Material*

Task	Stimuli	Retention Interval	Young Adults			Older Adults		
			N-P	N-O	P-O	N-P	N-O	P-O
<i>Studies Comparing Memory for Emotional and Neutral Material</i>								
<i>Yoder &amp; Elias, 1987</i>								
Free Recall	slide stories	immediately	-	N	-	-	N	-
Cued Recall	--  --	--  --	-	N	-	-	N	-
Free Recall	--  --	72 hours	-	N	-	-	N	-
Cued Recall	--  --	--  --	-	N	-	-	N	-
<i>Carstensen &amp; Turk-Charles, 1994</i>								
Free Recall	texts	60 min	-	N	-	-	N	-
<i>Kazui et al., 2000</i>								
Cued Recall	slide stories	5 min	-	-	-	-	N	-
<i>Fung &amp; Carstensen, 2003</i>								
Recognition	advertisements	?	-	-	=	-	-	P
<i>Studies Comparing Memory for Positive, Negative, and Neutral Material</i>								
<i>Knight et al., 2002</i>								
Free Recall	words	immediately	=	-	-	P	-	-
Free Recall	--  --	delayed (?)	P	-	-	P	-	-
Free Recall	texts	delayed (?)	-	=	-	-	=	-
<i>Kensinger et al., 2002</i>								
Free Recall	pictures	immediately	=	N	P	=	N	P
Free Recall	words	immediately	=	N	P	=	N	P
Free Recall	words embedded	immediately	=	N	P	=	N	P
Recognition	words embedded	5 min & 1 hr	-	N	-	-	N	-
<i>Charles et al., 2003 – Study 1</i>								
Free Recall	pictures	15 min	=	N	P	P	N	P
Recognition	--  --	after recall	N	N	=	=	=	=
<i>Charles et al., 2003 – Study 2</i>								
Free Recall	pictures	15 min	N	N	P	=	N	P
Recognition	--  --	15 min	N	N	=	=	=	=
<i>Mather &amp; Carstensen, 2001 – Study 1</i>								
Recognition	faces	10 min	P	N	P	=	=	=
<i>Mather &amp; Carstensen, 2001 – Study 2</i>								
Recognition	faces	10 min	=	N	P	P	=	P
<i>Denburg et al., 2003</i>								
Free Recall	pictures & narratives	24 hr	N	N	P	N	N	P
M-C Questions	--  --	24 hr	=	=	=	=	=	=
Recognition	--  --	24 hr	P	O	O	P	O	O
Free Recall	--  --	8 months	=	N	P	=	N	P
M-C Questions	--  --	8 months	=	=	=	=	=	=
Recognition	--  --	8 months	=	=	=	=	=	=
<i>Leigland et al., 2004</i>								
Free Recall	words	immediately	=	=	=	=	=	=
Free Recall	--  --	30 min	P	=	P	P	=	P
Recognition	--  --	after recall	=	N	P	=	N	P
Recognition	faces	30 min	P	O	=	P	O	=
<i>Comblain et al., 2004</i>								
Recognition	faces	14 days	N	N	=	N	N	=

*Note.* The columns compare memory for negative and positive material (N-P), for negative and neutral material (N-O), and for positive and neutral material (P-O). The letters indicate whether negative (N), positive (P), or neutral material (O) was better remembered or whether there was no difference in memory (=). - = This comparison was not assessed. ? = The authors did not report this information.

valence categories (=) or whether they remembered more negative (N), more positive (P), or more neutral material (O).<sup>4</sup>

### 2.2.1 Neutral versus Emotionally-Toned Material

Research in young individuals suggests that the emotional-tone of to-be-remembered material can influence memorability, in that emotionally-toned stimuli are often better remembered than neutral stimuli (see Chapter 1). In this section, I review four studies that investigated age-related differences in memory for neutral and emotionally-toned material (i.e., Carstensen & Turk-Charles, 1994; Fung & Carstensen, 2003; Kazui et al., 2000; Yoder & Elias, 1987; see Table 1). The studies are reviewed in the sequence of publication beginning with the earliest paper. I would like to mention at the outset that in these studies, the term “emotional” is typically used to refer to negatively-toned material.

Yoder and Elias (1987) reported the earliest age-comparative study that investigated memory for emotionally-toned material. In their study, memory performance for emotional stimuli was investigated with sequences of pictures that told a story, a so-called slide story. (Slide stories are similar to comic strips.) Two neutral and two emotional slide stories were presented to 16 young ( $M = 19.1$ , aged 18 to 22 years), 16 middle-aged ( $M = 39.4$ , aged 35 to 45 years), and 16 older women ( $M = 71.1$ , aged 65 to 75 years).<sup>5</sup> Each participant was asked to perform a cued-recall (i.e., a nine-question test of the story) and a free recall task immediately after presentation and 72 hours later. The analyses, whether for cued recall or for free recall, revealed three results: First, all age groups retained the emotional stories better than the neutral ones. Second, this emotional enhancement effect was greater after a delay than at immediate recall. And finally, despite a main effect for age (namely, older adults recalled less information than younger adults), all age groups benefited equally well in their recall of emotional content.

Carstensen and Turk-Charles (1994) used novels to examine age-related differences in memory for emotional and neutral phrases. The emotional phrases were for the most part sadness-related. (This information was not provided in the original Carstensen and Charles paper but in Knight, Maines, and Robinson, 2002.) After a retention interval of one hour, 23 young adults ( $M = 24.8$ , aged 20 to 29 years), 22 middle-aged adults ( $M = 41.3$ , aged 35 to 45

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<sup>4</sup> This procedure of simply presenting the direction of the effects is similar to early vote-counting procedures in literature reviews. Conclusions based on vote-counting procedures can be extremely misleading (e.g., Hedges & Olkin, 1980). Therefore, the pattern should be treated with caution. Unfortunately, some studies did not provide sufficient information to compute appropriate effect sizes for each age group.

<sup>5</sup> For all following studies, I report mean, standard deviation, and range of participants' age for each age group. When some information were missing, the study did not provide this information.



years), 18 older adults ( $M = 60.7$ , aged 53 to 67 years), and 20 elderly adults ( $M = 75.8$ , aged 70 to 83 years) were asked to recall two text passages (i.e., novels) as accurate as possible. The proportion of emotional versus neutral phrases recalled was determined. The proportion of phrases recalled revealed a linear age trend such that older age groups recalled relatively more emotional phrases than neutral phrases. This result depended exclusively on a reduction of neutral idea units recalled with age. The amount of emotional idea units recalled was practically the same across age groups.

Kazui and colleagues (Kazui et al., 2000) examined memory performance of 10 healthy older adults ( $M = 70.8$ ,  $SD = 5.5$ ) and 34 patients with early Alzheimer's disease ( $M = 71.6$ ,  $SD = 6.5$ ). Participants were asked to recall the story line of either a neutral or an emotional sequence of pictures. The two sequences were identical except for one passage in the middle of each story: one was negatively-toned and the other was not. The memory task consisting of a cued recall task with 11-item questions was administered 5 minutes after the presentation of the slide stories. The results indicated that older adults as well as Alzheimer's disease patients showed memory improvements for the emotionally-toned story.

Fung and Carstensen (2003) examined age differences in memory and preferences for advertisements. Participants, 82 younger ( $M = 27.4$ , aged 18 to 37 years) and 82 older ( $M = 71.3$ , aged 55 to 85 years) adults, saw six different product advertisements. For each product, three different versions of advertisements were created. Each version was identical except for the slogan. The slogans involved either an emotional message, a knowledge-related message, or no slogan (control condition). The emotional messages were related to love and concern (i.e., positively-toned). Advertisement versions were balanced across and within participants. After viewing the advertisements, participants were asked to recognize the brand names and slogans of the presented products. The results revealed that older adults remembered a greater proportion of information from the emotional slogans than from the knowledge-related or neutral slogans. Younger adults, in contrast, remembered an equally high proportion of information across versions.

Although these studies used very different to-be-remembered material, the findings of all studies suggest that older adults show enhanced memory for emotionally-toned material documenting a well-preserved enhancement effect of memory by emotion in old age (see Table 1). Moreover, the studies by Carstensen and Turk-Charles (1994) and by Fung and Carstensen (2003) suggest that this enhancement effect is even stronger in old age.

Considering the fact that three studies used negative to-be-remembered material (one exception is the study by Fung & Carstensen, 2003), these studies are also relevant for

possible age-related differences in the positive-negative disparity in emotional memory. Interpreting these findings as an enhancement effect for negatively-toned material over neutral material, older adults showed similar or even stronger enhancement effects for negatively-toned material than young adults signifying no general reduction in remembering negative material in old age. Thus, the capacity to remember negatively-toned material seems to be well-preserved in old age. However, the findings by Fung and Carstensen suggest that older adults remember positively-toned material better than neutral material and more so than young adults.

### 2.2.2 Positive versus Negative Material

The studies that have investigated memory for neutral and emotionally-toned material in young and older adults give some hints about age-related differences in the positive-negative disparity in memory for emotionally-toned materials. Although these studies are informative for the general enhancement of memory by emotion, only studies which considered negative and positive to-be-remembered material within one experiment can give an unambiguous answer to the question of age-related differences in the positive-negative disparity of emotional memory. Nine studies examined differential effects of aging on the memory performance for positively and negatively toned material. Findings from these studies are inconsistent, leaving space for speculations about age-related differences in emotional memory and related mechanisms. In the following, I review these studies in detail by focusing on information for the positive-negative disparity in memory (see also Table 2).

The study by Knight, Maines, and Robinson (2002) was designed to examine mood congruency effects in young and older adults. Although this study was not directly intended to examine age-related differences in emotional memory, the control group offered some information for age-related differences in the positive-negative disparity in memory. For this reason, I focus here primarily on the control group, in which 64 young ( $M = 21.41$ ,  $SD = 3.82$ , aged 18 to 35) and 33 older adults ( $M = 76.52$ ,  $SD = 7.38$ , aged 62 to 90) participated.

The study included four memory tasks: (a) an immediate word recall task for 12 positive and 12 negative nouns equated for word frequency, (b) a delayed word recall task for the same words, (c) a text recall task for a text passage already used by Carstensen and Turk-Charles (1994), and (d) an autobiographical memory task (for this task, see section 2.1). In the word recall task, positive and negative words were mixed together in a heterogeneous list and were read aloud with a 1-second interval between words. Participants were asked to freely recall the words immediately and with a delay after presentation. The text passage

consisted of 21 neutral, 25 negative, and 3 positive idea units documenting the fact that the text passages used by Carstensen and Turk-Charles were predominantly negatively-toned. (This was the case not only for this text passage but also for the other text passage used by Carstensen and Turk-Charles.) Despite the dominance of negative information, the text passage provided negative, positive, and neutral information in an emotion-heterogeneous context. For the delayed word recall and for the text recall, Knight and colleagues (2002) did not report details about the length of the retention interval in general nor whether this delay differed by age group. However, the delayed recall and the text recall were within the same session.

For the word recall tasks, the proportion of negative and positive words recalled were computed in relation to the total number of words recalled, including intrusions. Therefore, the sum of negative and positive proportion of words recalled does not completely add to 100%. Knight and colleagues (2002) focused on a comparison of different experimental conditions and not on the positive-negative disparity of emotional memory. Unfortunately, the reported analyses were done separately for positive and negative words: They did not report analyses that directly compared memory performance for positive and negative material. However, looking at the proportions of the immediate word recall task in the control group, the data suggests an interaction between age and valence. Young adults recalled similar proportions of positive (43%) and negative words (42%), whereas older adults recalled a greater proportion of positive (47%) than negative words (38%). For the delayed word recall, the pattern seems to indicate that young adults recalled a greater proportion of positive (42%) than negative words (36%), whereas this discrepancy was even larger for the older adults (positive: 46%, negative: 30%). In sum, older adults' memory showed a positivity effect in remembering words from an emotion-heterogeneous context whereas young adults' memory did not reveal a memory bias. Given no statistical test for this inference, this interpretation should be considered with caution.

For the text recall, the positive idea units of the text passage were omitted from the analyses making this task a simple comparison between remembering negative and neutral phrases. Analyses of the proportion of phrases recalled from the text revealed no significant effect. In particular, there were no significant main effects of age and valence and no significant interaction between age and valence. Both age groups recalled similar proportions of negative and neutral phrases. This finding is in contrast to the findings by Carstensen and Turk-Charles (1994) who found that older adults recalled proportionally more emotional than neutral phrases for the same text passage. The null finding by Knight and colleagues (2002)

might be due to a floor effect in the recall data: From all phrases, young and older adults recalled only 26% and 22%, respectively.

In sum, the study by Knight, Maines, and Robinson (2002) showed some evidence for a positivity effect in the immediate and delayed word free recall task. However, the text recall task resulted in no age-related differences in remembering negatively-toned phrases.

Kensinger and colleagues (2002) investigated the effects of normal aging and Alzheimer's disease on emotional memory. In Alzheimer's disease patients, it is known that there is a substantial decline in volume of the amygdala. This shrinkage begins even in early stages of Alzheimer's disease. In so far as the amygdala is thought to be responsible for the memory enhancement effect of emotional stimuli (e.g., Cahill et al., 1996; Hamann, 2001; Maren, 1999), patients in early stages of Alzheimer's disease are expected to show impaired memory enhancement for emotional stimuli. In normal aging, only modest reductions of amygdaloid volume occur (C. D. Smith, et al., 1999). Thus, healthy older adults might show only mild or no impairment in emotional memory in comparison to younger adults.

To test these predictions, 20 young adults ( $M = 20.5$ ,  $SD = 1.9$ ), 20 older adults ( $M = 73.3$ ,  $SD = 3.2$ ), and 13 patients with early Alzheimer's disease ( $M = 75.6$ ,  $SD = 6.2$ ) were administered four tests of memory performance for emotional stimuli (Kensinger et al., 2002). The four tests were (a) a recall test for 15 positive, 15 negative and 15 neutral pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999); (b) a recall test for 9 positive, 9 negative and 9 neutral words taken from the Affective Norms of English Words (ANEW; Bradley & Lang, 1999); (c) a word-embedded recall test for 30 neutral words set in 10 positive, 10 negative, and 10 neutral self-generated sentences; and (d) a recognition test of neutral and negative words in a neutral or negative embedded sentence (e.g., "The *sailor* was responsible for the *dock*." Or "The *sailor* was responsible for the *rape*."). To avoid ceiling or floor effects, the procedure differed for young and older adults: older adults either viewed the set of stimuli twice (for picture recall and word recall) or performed the memory task after a 5-min delay (word recognition), whereas younger adults either viewed the set of stimuli only once or performed the memory task after a 1-h delay. For the presentation of the to-be-remembered material in all four tasks, the list composition was heterogeneous: negative, positive, and neutral material were mixed together in the list. During the presentation of the pictures in the picture recall task and the words in the word recall task, participants rated the stimuli as positive, negative, or neutral. Therefore, it was possible to compare memory performance not only based on a priori (objective) valence categories but also based on individual (subjective) valence categories.

The mixed analyses of variance of Kensinger and colleagues (2002) revealed no significant main effects for age, but significant main effects for the type of stimuli. Younger and older adults recalled more emotional stimuli than neutral stimuli. This result was valid for all four tasks. In the three tasks that allowed comparison of positive and negative stimuli, the interactions between age and valence were not significant for a priori valence categories. However, the analyses based on subjective valence categories revealed significant interactions between age and valence for the word recall and the word-embedded recall task. Younger adults recalled more positive than negative words in the word recall and word-embedded recall task. Older adults, in contrast, were better able to recall negative than positive words in both tasks. In the picture recall task, younger and older adults did not differ in the recall of positive and negative pictures.

In sum, the study by Kensinger and colleagues (Kensinger et al., 2002) did not provide any evidence for an advantage of positively-toned material in older adults' memory. Quite the opposite, the analyses on subjective valence categories suggested that young adults recall positive words better than negative words whereas older adults recall negative words better than positive words. However, this finding was restricted to the analyses of subjective valence categories and did not generalize to the a priori valence categories. Nevertheless, the discrepant finding for subjective and a priori valence categories highlights the importance of interindividual differences in perceiving stimuli.

Charles, Mather, and Carstensen (2003) examined age differences in the memory for positive and negative pictures in two studies. In Study 1, 48 younger ( $M = 24.56$ ,  $SD = 2.84$ , aged 18 to 29), 48 middle-aged ( $M = 46.83$ ,  $SD = 3.62$ ) and 48 older adults ( $M = 70.98$ ,  $SD = 3.62$ , aged 62 to 90) were shown 32 pictures from the IAPS, 16 neutral, 8 positive and 8 negative images. Pictures were presented consecutively at 2-s intervals. For the presentation, positive, negative, and neutral pictures were mixed together. Approximately 15 minutes after presentation, participants were asked to write down a description of each image they could recall. Afterwards, participants did a picture recognition task.

For the picture recall task, the results revealed that older adults, in contrast to middle-aged and younger adults, recalled fewer images overall. Considering the relative proportion of positive, negative, and neutral pictures recalled, all three age groups recalled significantly more positive and negative pictures than neutral ones. Middle-aged and older adults, however, recalled a greater number of positive images compared to negative images. Younger adults, in contrast, recalled similar numbers of positive and negative pictures.

The analyses of the picture recognition task showed main effects of valence and age, and a significant interaction between age and valence. Middle-aged adults correctly recognized a greater proportion of images than both, younger and older adults did. Additionally, negative images were better recognized than either positive or neutral images. Considering the relative proportion of valence-type within age groups, younger adults recognized more negative images than positive and neutral ones. Middle-aged and older adults, in contrast, recognized equal proportions of valence-type images.

In Study 2, similar to Study 1, Charles and colleagues (2003) presented 32 young ( $M = 23.53$ ,  $SD = 3.14$ , aged 19 to 30) and 32 older ( $M = 74.06$ ,  $SD = 6.55$ , aged 63 to 86) adults pictures. For this purpose, 52 positive, 52 negative and 52 neutral pictures were taken from the IAPS. Half of the pictures were used in the initial presentation; the other half was used as contrasts in the recognition task matched for valence and arousal. In contrast to Study 1, participants had the option to determine how long they liked to see each picture until the next appear on the screen. The authors argued that older adults generally prefer to avoid negatively-toned materials and to approach positively-toned materials. These motivationally-based preferences should result in shorter self-determined viewing times for negative pictures than for positive pictures. As in Study 1, approximately 15 minutes after self-paced picture presentation, participants were asked to perform a picture recall and a picture recognition task.

The analyses of the time participants took to view each picture revealed that younger and older adults viewed negative pictures longer than either positive or neutral pictures. Neither the main effect of age nor the interaction of age and valence reached significance. This finding did not support the prediction of shorter viewing times for negative pictures in older adults.

The analyses of the pictures recalled showed a significant main effect of valence: Negative images were better recalled than positive images, which were in turn better recalled than neutral images. A main effect of age revealed that younger adults recalled more images overall. The interaction between valence and age was also significant. Younger adults recalled more negative images than positive images, and more positive than neutral images. Older adults, in contrast, recalled an equal number of negative and positive images, but a significant smaller number of neutral pictures.

The picture recognition data of Charles and colleagues (2003) revealed a significant main effect of valence. Negative images were recognized in a greater proportion than positive and neutral images. A significant interaction between valence and age showed that younger

adults correctly recognized a greater proportion of negative images compared to positive and neutral images. Older adults, in contrast, correctly recognized an equal number of negative, positive, and neutral images.

Overall, the studies by Charles, Mather, and Carstensen (2003) provided some support for age-related differences in the positive-negative disparity. Moreover, this study became the basis for the proposed positivity effect in older adults' memory (see Carstensen & Charles, 2003). Young adults remembered negatively-toned pictures better than positively-toned whereas older adults showed no memory differences between negatively- and positively-toned pictures. Despite the fact of a relative advantage of positively-toned pictures relative to negatively-toned pictures in older adults' memory than in young adults' memory, the pattern is probably more accurately described as a negativity effect in young adults (or a reduced negativity effect in older adults).

Mather and Carstensen (2003) investigated attentional and memory biases to emotional faces in two studies. In Study 1, 52 young adults ( $M = 25.8$ ,  $SD = 5.6$ , aged 18 to 35 years) and 52 older adults ( $M = 74.0$ ,  $SD = 6.1$ , aged 62 to 94 years) did a dot-probe task. On a computer screen, an emotional version and a neutral version of one face were displayed. The emotional version of the face showed either a happy, a sad, or an angry expression. Both, the emotional and the neutral face, were displayed for 1000 ms. Afterwards, the two faces disappeared from the screen and a small dot appeared in the location of one of the two face versions. Participants were asked to press one of two keys indicating the position of the dot. During the dot-probe task, participants saw 30 face pairs in an emotion-heterogeneous manner. Each pair was presented four times, so that the emotional tone of the face and dot location could be fully counterbalanced.

After a 10-min delay, participants were given a face recognition task. During the task, one face appeared on the screen and participants had to indicate if they had seen the face in the previous part or not. The task included 60 different faces. Thirty faces had previously been seen and 30 faces were completely new. Half of each type showed emotional expressions, whereas the other half showed neutral expressions. This procedure permitted the computation of four different recognition scores: (a) positive faces seen at test and positive-neutral pairs seen at encoding, (b) neutral faces seen at test and positive-neutral pairs seen at encoding, (c) negative faces seen at test and negative-neutral pairs seen at encoding, and (d) neutral faces seen at test and negative-neutral pairs seen at encoding. However, no mention was made why faces with sad expressions and faces with angry expressions were combined into one category of negative faces.

The results are relative complex because of differential effects for emotional faces and neutral faces. Regarding only the emotional faces at test, younger adults recognized more positive faces (proportion of faces correctly recognized:  $M = .57$ ) than negative faces ( $M = .46$ ), whereas older adults showed no differences between positive ( $M = .35$ ) and negative faces ( $M = .34$ ). Regarding the neutral faces at test, younger adults showed no differences between neutral faces accompanied with a positive expression ( $M = .43$ ) and neutral faces accompanied with a negative expression at encoding ( $M = .42$ ), whereas older adults recognized more neutral faces shown with positive faces ( $M = .41$ ) than neutral faces shown with negative faces ( $M = .28$ ). However, the analyses revealed a significant main effect of valence at encoding indicating that both age groups recognized more faces (neutral and emotional) if presented with a positive expression than with a negative expression.

In Study 2, the same procedure was applied. Forty-four young adults ( $M = 25.4$ ,  $SD = 4.8$ , aged 18 to 35 years) and 44 older adults ( $M = 71.5$ ,  $SD = 5.5$ , aged 60 to 81 years) completed the dot-probe task followed by a 10-min delay interval. Instead of a simple recognition task, a forced-choice recognition task was used. Participants saw two different faces with the same emotional expression. One of these faces had been seen before and one had not.

Similar to Study 1, the analyses showed a significant main effect of valence at encoding: Faces presented with positive expressions at encoding were better recognized than faces presented with negative expressions. However, regarding only emotional faces at test, younger adults showed no differences between positive ( $M = .82$ ) and negative faces ( $M = .81$ ), whereas older adults remembered more positive faces ( $M = .72$ ) than negative faces ( $M = .62$ ). For both age groups, no differences were found between neutral faces accompanied by positive faces ( $M_{young} = .80$ ,  $M_{old} = .63$ ) or by negative faces ( $M_{young} = .76$ ,  $M_{old} = .64$ ).

The findings in the studies by Mather and Carstensen (2003) are rather complex. They differ for emotional and neutral faces at test and between Study 1 and Study 2. However, in general, young and older adults recognized either more positive than negative faces or showed no differences in recognizing positive and negative faces. Importantly, no age group showed enhanced memory for negative faces.

Denburg and colleagues (2003) examined emotional memory in three age groups: 26 young ( $M = 43.2$ ,  $SD = 5.4$ , aged 35 to 51 years), 27 middle-aged ( $M = 60.5$ ,  $SD = 5.5$ , aged 52 to 69 years), and 27 older adults ( $M = 76.4$ ,  $SD = 4.8$ , aged 70 to 85 years). Participants saw 15 pictures: 5 positive, 5 neutral, and 5 negative pictures. The pictures were presented in blocks of valence categories but consecutively resulting in emotion-heterogeneous



conditions. The order of the blocks was counterbalanced across subjects. Each picture was accompanied by one narrative sentence read by the experimenter.

Following a 24-hour delay, participants were asked to carry out three memory tasks. The tasks were (a) a free recall task, (b) a multiple-choice questions task, and (c) a four-alternative forced-choice recognition task. In the free recall task, participants were asked to write down a short description of each picture and to write down each narrative sentence they could recall. Participant's answers were scored as correct if either they wrote a correct description of one picture or they recalled the accompanied sentence of this picture. After the free recall task, participants completed the multiple-choice questions task. For each picture, six multiple-choice questions were created resulting in 90 questions overall. Finally, participants did a four-alternative forced-choice recognition task for the pictures. They saw four pictures of the same scene simultaneously. One picture was the original picture and the other three differed only in minor changes from the original picture.<sup>6</sup>

For the free recall task, Denburg and colleagues (2003) found significant main effects for age and valence. Young adults recalled more pictures than older adults did. Additionally, all age groups recalled more negative pictures than positive and neutral pictures, and the positive pictures better than the neutral pictures. The interaction between age and valence was not significant. The analyses for the multiple-choice questions revealed a significant main effect of age that young adults performed significantly better than middle-aged and older adults. Neither the main effect of valence nor the interaction effect reached significance. The analyses for the forced-choice picture recognition task showed a significant main effect for age. Young adults recognized more pictures correctly than older adults did. In addition, a significant main effect of valence showed the opposite pattern as in the free recall task. For all age groups, neutral pictures were better recognized than positive and negative pictures, and the positive pictures were better recognized than the negative pictures.

After an 8-months delay, 9 young, 22 middle-aged, and 12 older adults completed the three memory tasks again. Compared to the 24-hours delay, the last task was exchanged because of expected floor effects. Instead, participants performed a simple picture recognition task (yes/no) with 15 new distractor stimuli.

For all three tasks, there was a significant main effect for age. Young adults remembered more information than older adults did. The analyses for the free recall task

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<sup>6</sup> Note that there are some inconsistencies in the manuscript of Denburg and colleagues (2003). Values in the presented figures do not match to the range of possible values as indicated in the method section. However, the displayed pattern seems to fit to the reported analyses.

showed a significant main effect of valence, in which positive and negative stimuli were better recalled than neutral ones. The analyses for the other memory tasks, however, showed neither a main effect of valence nor an interaction effect of age and valence. In sum, no significant Age x Valence interactions were found across all tasks.

Taken together, the findings by Denburg and colleagues (2003) did not support proposals about age-related differences in the positive-negative disparity. Aside from the main effect of age, that young adults remember more information than older adults, there was no evidence for age-related differences in remembering positive, negative, or neutral stimuli. However, the limited set of to-be-remembered stimuli (i.e., 5 stimuli per valence category) almost certainly resulted in reduced variability across the valence categories. This may hinder the opportunity to find age-related differences in remembering emotionally-toned stimuli.

Leigland, Schulz, and Janowsky (2004) investigated memory performance of 25 young ( $M = 23.9$ , aged 18 to 35 years) and 36 older adults ( $M = 72.3$ , aged 63 To 81 years) on two different kinds of emotionally-toned materials: words and faces. In the word task, an emotion-heterogeneous list of 27 words was constructed consisting of three categories intended to represent negative, neutral and positive words (nine words in each category). Across the three categories, the words were matched for frequency and word length. Participants were asked to rate each word for pleasantness on a five-point scale (1 = negative, 3 = neutral, 5 = positive). No mention was made of a later memory task. Immediately after completing the word ratings and after a 30-min delay again, participants were asked to recall as many words as possible from the list. After the second recall, participants performed a written yes/no recognition test for the words. They were presented with a 54-word list composed of the 27 target words and 27 distracter words.

For the face stimuli, participants viewed 28 faces during the 30-min retention interval between word ratings and second word recall. For the presentation, faces expressing various emotions were mixed together into one emotion-heterogeneous sequence of faces. Participants were asked to rate the faces for pleasantness on the same five-point scale as used for the words. Again, no mention was made of a later memory task. Faces of four males and two females were drawn from a set by Ekman and Friesen (1976) expressing a variety of emotions (happy, neutral, fearful, angry, sad, disgusted, surprised, disapproving). After a 30-min retention interval, participants were given a yes/no recognition test with 54 faces (27 old and 27 novel stimuli). All participants saw the stimuli in the same order.

Leigland and colleagues (2004) conducted analyses on the proportions of each valence category in relation to the overall score. Thus, adding the proportions of positive,

negative, and neutral categories would result in 100%. That said, the major analyses were done on linearly dependent variables and so should be treated with caution.

Regardless of these statistical problems, the analyses for the word recall tasks showed significant main effects of age at immediate testing as well as at the 30-min delay. Young adults recalled significantly more words than older adults at both time points. The main effect of valence was significant at the 30-min delay suggesting that both, young and older adults, recalled more positive words than negative or neutral words. At both time points, the interaction effect between valence and age was not significant for the word recall tasks.

In the word recognition task, the main effects of age and valence were significant. Young adults recognized more words correctly than older adults did; and both age groups recognized more emotional words (positive and negative words) than neutral words. There was a trend ( $p < .10$ ) that, over and above the main effect of valence that participants recognized a greater proportion of positive words, older adults recognized even a greater proportion of positive words. However, young adults recognized 93% of all words correctly suggestive of a ceiling effect in the word recognition data of young adults.

The analyses for the face recognition task revealed no main effect of age and no interaction effect between age and valence. A main effect of valence showed that both age groups recognized proportionately more faces with a neutral or positive expression than faces with a negative expression.

In sum, the study by Leigland, Schulz, and Janowsky (2004) did not generally support the idea of a positivity effect in older adults' memory. There was some indication for such an effect in the word recognition data where there was a trend for a greater positivity effect in older adults. However, this trend is probably an artifact due to a ceiling effect in the word recognition performance of young adults. The other tasks, the word recall tasks and the face recognition task, showed no evidence for age-related differences in the positive-negative disparity of emotional memory.

Comblain, D'Argembeau, Van der Linden, and Aldenhoff (2004) investigated age-related differences in recognition memory for emotionally-toned pictures. Twenty young adults ( $M = 22.5$ , aged 18 to 25 years) and 20 older adults ( $M = 67.5$ , aged 60 to 70 years) were enrolled in this experiment. The sample was stratified by sex. Both age groups were matched for years of education. The pictures consisted of two sets of 60 pictures that were counterbalanced across participants. Positive, negative, and neutral pictures were mixed together in the presentation. Each participant was asked to rate one set of pictures for pleasantness, arousal, and visual complexity. Each picture appeared for 2 seconds on the

screen. Afterwards, the rating scales appeared on the screen until participants made their responses. Two weeks later, participants were given a remember/know recognition task with both sets of pictures as stimuli.

For the analyses, Comblain and colleagues (2004) divided the set of 60 pictures into three categories based on the ratings of valence and arousal obtained in the experiment. Thus, they used a post-hoc valence categorization. They found that positive, negative, and neutral pictures, as well as pictures selected as low-, medium-, and high-arousing, differed in visual complexity. To avoid interpretation problems by analyzing stimuli that differ by visual complexity, Comblain and colleagues selected for the analyses of valence effects 10 negative, 10 positive, and 10 neutral pictures from the presented and to-be-remembered set of 60 pictures. Similarly, for the analyses of arousal effects, 10 high-arousing, 10 medium-arousing, and 10 low-arousing pictures were selected. No comments were made to what extent the selected sets of 30 pictures for the valence analyses and 30 pictures for the arousal analyses overlap. This selection procedure was done for both sets of 60 pictures. For both dimensions, valence and arousal, the analyses were done separately for the post-hoc selected sets of 30 pictures. At this point, I would like to note that this post-hoc selection procedure assumes local independency, that is, memory for one stimulus is independent from any other stimuli (see reviews of item response theory, Embretson & Reise, 2000; Rogers, H. J., Swaminathan, & Hambleton, 1991).

All analyses were done on the proportion of hits and on the discrimination measure  $d'$ . Both measures yielded very similar results. Comblain and colleagues (2004) analyzed in a first step the simple yes/no recognition performance for valence and arousal. In a second step, they analyzed the remember (R), know (K), and guess (G) responses separately.

For valence, the analyses of the simple yes/no recognition data revealed main effects of age and valence. Young adults recognized more pictures correctly than older adults. And both age groups recognized more negative pictures than positive and neutral pictures. The difference between positive and neutral pictures was not significant. The interaction between age and valence was also not significant.

Follow-up analyses of valence effects in the remember/know paradigm revealed a more complex picture. The analyses of R responses showed significant main effects of age and valence, and an interaction effect between age and valence. Younger adults reported more R responses for negative (hits = 80%) than for positive pictures (50%) and more R responses for positive than for neutral pictures (41%). Older adults reported also more R responses for negative (45%) than for positive (27%) or neutral pictures (28%). But they

reported an equivalent number of R responses for positive and neutral pictures. In addition, young adults gave more R responses than older adults for positive and negative pictures but not for neutral pictures. For K responses, a main effect of valence and an age by valence interaction were obtained. Older adults, in contrast to younger adults, reported more K responses for negative (Young: 11%, Older: 21%) but not for positive (Young: 29%, Older: 28%) or neutral pictures (Young: 30%, Older: 24%). For G responses, a main effect of valence documented that both age groups indicated more guessing for positive and neutral pictures than for negative pictures.

The analyses of arousal effects were done equivalently to the analyses of valence effects. The analyses of the yes/no recognition data showed a main effect of age that young adults recognized more pictures than older adults. A main effect of arousal documented that high-arousing pictures were better recognized than medium- or low-arousing pictures. The recognition data for medium- and low-arousing pictures did not differ.

The analyses of arousal effects in R responses revealed a main effect of age that young adults reported more R responses than older adults. A main effect of arousal showed that high-arousing pictures received more R responses than medium-arousing pictures, which again received more R responses than low-arousing pictures. For K responses, a main effect of arousal revealed that low-arousing pictures received more K responses than high-arousing pictures. For G responses, a main effect of arousal showed that participants guessed more for low- than medium-arousing pictures and more for medium- than for high-arousing pictures.

In sum, the study by Comblain and colleagues (2004) provided no evidence for age-related differences in the positive-negative disparity. Young and older adults recognized more negative pictures than positive pictures. Although the follow-up comparisons for Remember (R), Know (K), and Guess (G) responses showed a somewhat more complex picture especially with regard to the neutral valence category, the general picture was supported. The significant interactions between age and valence for the R and K responses were most likely due to general age-related differences in recognition performance. For negative words, young adults reported much more R responses than older adults that has to result in less K responses for the young adults compared with the older adults.

### **2.2.3 Summary of Findings**

There is a growing number of studies investigating age-related differences in remembering emotionally-toned material. The experiments that are reviewed here can be divided into two major categories (see Table 1). On the one hand, four studies investigated

age-related differences in memory for emotional and neutral material. These studies could not directly inform about the proposed positivity effect in older adults' memory. However, these studies provide converging evidence that older adults show an enhancement effect of memory by emotion. On the other hand, nine studies compared memory for positive, negative, and neutral material in young and older adults. The findings of these studies are directly relevant for age-related differences in the positive-negative disparity of emotional memory. However, the findings of these studies are inconsistent.

Table 2 summarizes additional information about the sample characteristics of the reviewed studies. For each age group, mean, standard deviation, and range of participants' age are provided as well as information about sample size and percent females. In addition, Table 2 indicates whether the sample was stratified by sex and education level. This design and sample information may be useful to determine some sources of inconsistency in findings and in relation to the primary research question of the literature review: Is there a clear pattern of age-related differences in remembering positive, negative, and neutral material?

Considering the general enhancement of memory by emotion, the findings are clear-cut. Basically all studies reviewed here suggest that young and older adults remember emotionally-toned material better than neutral material. This is the case for positive and negative to-be-remembered material. From the total set of 55 comparisons between negative and neutral material for young and older adults in the studies summarized in Table 1, 35 revealed a memory advantage for negative material, 16 showed no significant differences, and 4 comparisons showed better memory for neutral than for negative material. In comparing positive and neutral material, 21 of the total set of 40 comparisons revealed a memory advantage for positive over neutral material; 17 comparisons showed no significant differences, and 2 comparisons revealed a memory advantage for neutral material. Even though vote-counting procedures can be misleading (e.g., Hedges & Olkin, 1980), the pattern is rather consistent across studies: Positive and negative material is typically better remembered than neutral material.

There is no evidence for negative age differences in the general enhancement of memory by emotion. The memory enhancement for positive and negative to-be-remembered material seems to be well-preserved in old age. This finding is good news for older adults in light of a general decline in cognitive functioning. The literature review does also not support proposals about an age-related increase in the operation of emotion in memory (Carstensen & Turk-Charles, 1994). The pattern across studies is rather consistent for young and older

Table 2

*Sample Characteristics of Experimental Studies*

	N	Participants' Age			% Females	Stratified by	
		M	SD	Range		Sex	Edu.
<i>Yoder &amp; Elias, 1987</i>							
Young Adults	16	19.1	?	18-22	100%	-	-
Middle-aged Adults	16	39.4	?	35-45	100%	-	-
Older Adults	16	71.1	?	65-75	100%	-	-
<i>Carstensen &amp; Turk-Charles, 1994</i>							
Young Adults	23	24.8	?	20-29	? <sup>a</sup>	-	-
Middle-aged Adults	22	41.3	?	35-45	? <sup>a</sup>	-	-
Older Adults	18	60.7	?	53-67	? <sup>a</sup>	-	-
Elderly Adults	20	75.8	?	70-83	? <sup>a</sup>	-	-
<i>Kazui et al., 2000</i>							
Healthy Older Adults	10	70.8	5.5	?	?	-	-
Alzheimer's Disease Patients	34	71.6	6.5	?	79.4%	-	-
<i>Fung &amp; Carstensen, 2003</i>							
Young Adults	80	27.4	?	18-37	50.0%	x	x
Older Adults	84	71.3	?	55-85	50.0%	x	x
<i>Knight et al., 2002</i>							
Young Adults	64	21.4	3.8	18-35	79.8%	-	-
Older Adults	33	76.5	7.4	62-90	67.9%	-	-
<i>Kensinger et al., 2002</i>							
Young Adults	20	20.5	1.9	?	?	-	-
Older Adults	20	73.3	3.2	?	?	-	-
Alzheimer's Disease Patients	13	75.6	6.2	?	?	-	-
<i>Charles et al., 2003 – Study 1</i>							
Young Adults	48	24.6	2.8	18-29	50.0%	x	-
Middle-aged Adults	48	46.8	3.6	41-59	50.0%	x	-
Older Adults	48	71.0	4.6	65-80	50.0%	x	-
<i>Charles et al., 2003 – Study 2</i>							
Young Adults	32	23.5	3.1	19-30	50.0%	x	-
Older Adults	32	74.1	6.5	63-86	50.0%	x	-
<i>Mather &amp; Carstensen, 2003 – Study 1</i>							
Young Adults	52	25.8	5.6	18-35	57.7%	-	-
Older Adults	52	74.0	6.1	62-94	59.6%	-	-
<i>Mather &amp; Carstensen, 2003 – Study 2</i>							
Young Adults	44	25.4	4.8	18-35	63.6%	-	-
Older Adults	44	71.5	5.5	60-81	63.6%	-	-
<i>Denburg et al., 2003</i>							
Young Adults	26	43.2	5.4	35-51	46.1%	-	-
Middle-aged Adults	27	60.5	5.5	52-69	51.8%	-	-
Older Adults	27	76.4	4.8	70-85	51.8%	-	-
<i>Leigland et al., 2004</i>							
Young Adults	25	23.9	?	18-35	63.9%	-	x
Older Adults	36	72.3	?	61-81	56.0%	-	x
<i>Comblain et al., 2004</i>							
Young Adults	20	22.5	?	18-25	50.0%	x	x
Older Adults	20	67.5	?	60-70	50.0%	x	x

Note. Edu. = Education. ? = The authors did not report this information. <sup>a</sup>Across age groups, 53% were females.

adults. One has to admit, however, that vote-counting procedures are not sensitive for the size of an effect. Thus, it might well be that age-related differences in the size of the enhancement of memory by emotion are not apparent in this review.

Regarding age-related differences in the positive-negative disparity of emotional memory, findings are inconsistent. Indeed, each new study in the literature appears to contribute a different finding. Furthermore, within studies, different findings are generated for different tasks, different to-be-remembered materials, and different retention intervals. The large heterogeneity in the assessment of memory for emotionally-toned materials documents the need for a systematic investigation of age-related differences in the positive-negative disparity of emotional memory.

Knight and colleagues (2002) found a different pattern in the immediate and the delayed word recall task for young and older adults. Young adults recalled an equal number of positive and negative words in the immediate recall task whereas young adults recalled more positive words in the delayed recall task. Older adults recalled more positive than negative words in the immediate recall task and this discrepancy increased in the delayed recall. This pattern of findings seems to suggest that both age groups forgot negative words easier than positive words. This would be evidence for the proposal that with longer retention intervals people tend to remember relative more positively- than negatively-toned materials (e.g., Taylor, 1991).

The results by Kensinger and colleagues (2002) showed mainly no differences for positively- and negatively-toned materials. However, based on subjective valence categories, the analyses revealed some significant interaction effects between age and valence. These interaction effects suggest that older adults are better able to recall negative than positive material. In contrast to younger adults, who are better able to recall positive than negative material. The interaction effects were found for the word recall and word-embedded recall tasks. The discrepant memory pattern between a priori valence categories and subjectively generated valence categories indicates the significance of the individual connotation attached to the materials.

Charles and colleagues (2003) found in two studies a significant interaction between age and valence. Younger adults are better able to recall and recognize negative pictures in contrast to older adults, who showed either better recall for positive pictures (Study 1) or no differences between positive and negative pictures (Study 2).

The findings by Mather and Carstensen (2003) are somewhat hard to interpret, because there were different patterns of results for emotional and neutral faces and for both studies. However, the analyses in both studies showed a significant main effect of valence at encoding, indicating that both age groups recognized more faces (emotional and neutral) presented with a positive than with a negative expression.



Denburg and colleagues (2003) found no significant interaction effect between age and valence. After a 24-hr delay, they found that all age groups recalled more negative pictures than positive pictures, all age groups showed no significant differences between the multiple-choice questions for positive and negative pictures, and finally, all age groups recognized more positive pictures than negative pictures in the forced-choice recognition task. After an 8-months delay, Denburg and colleagues found for all memory tasks no differences between positive and negative pictures. However, this seems to be due to a floor effect in the data and should not be overstated. In general, the study has a methodological problem because it combined the remembrance for pictorial and verbal material within one task. Moreover, the analyses rely on a very restricted set of to-be-remembered materials (5 negative, 5 positive, 5 neutral) that could question the generalizability of the observed findings.

Leigland and colleagues (2004) found no evidence for age-related differences in the positive-negative disparity of emotional memory. Interestingly, at immediate testing, participants showed no memory differences between positively- and negatively-toned words, but after a 30-minute interval, participants recalled and recognized more positive words and positive faces respectively. This pattern would also support the idea that the positive-negative disparity pattern differs by retention interval favoring positively-toned material with longer retention intervals. However, the study has also some major problems regarding the statistical analyses. Thus, these findings should be interpreted with caution.

Comblain and colleagues (2004) found that both young and older adults recognize more negative pictures than positive and neutral pictures. However, in an attempt to avoid interpretation problems, the authors analyzed only a subset of pictures that were matched for visual complexity. This procedure of analyzing only a subset of the to-be-remembered stimuli is only valid under the assumption of local independency of the items. This means that remembering one picture is independent from remembering other pictures. This assumption is probably not valid. In particular, if participants create chunks to organize the to-be-remembered material, the stimuli are no longer independent. For example, remembering the word “chair” from a list of objects may depend also on remembering the word “table” in the list. The authors stated in a footnote that they found similar results by analyzing the total set of pictures. However, the findings should be treated with caution.

Overall, there was no clear tendency for age-related differences in memory for negatively- and positively-toned materials across studies. Moreover, the results are not only inconsistent across studies; the results are also inconsistent across tasks within one study

making a statement about a general trend uncertain. Many studies show methodological flaws that likely contribute to the heterogeneity of findings. Aside from the methodological problems, very different approaches were used to investigate memory for emotionally-toned materials. Although these studies involved different types of stimuli and memory tasks, they all had one design feature in common; they all used emotion-heterogeneous lists of to-be-remembered material. In the next section, the influences of different approaches are outlined and discussed.

### **2.2.4 Potential Reasons for Inconsistent Findings about the Positive-Negative Disparity**

In the following paragraphs, I discuss five potential reasons for the observed inconsistent findings in studies investigating age-related differences in the positive-negative disparity of emotional memory. These factors are (a) the type of to-be-remembered material (e.g., pictures, words), (b) the selection procedure for the to-be-remembered material (e.g., matched for age groups), (c) the type of memory task (e.g., recall, recognition), (d) the number of memory tasks within one sample, and (e) the different retention intervals used.

First, findings could rely on the type of the to-be-remembered materials used. Most studies used pictorial material as to-be-remembered material. One reason for this is probably that it is relatively easy to find positively- or negatively-toned pictures. However, pictures are relatively complex stimuli that could differ on many dimensions. For example, positive, negative, and neutral pictures differ in the amount of visual information provided (e.g., Comblain et al., 2004): Negative pictures are visually more complex than positive pictures, and these are visually more complex than neutral pictures. The processing of visual information could interfere with the actual interest in showing differential memory for positive, negative, and neutral materials.

Pictures of faces (as used in Leighland et al., 2004; Mather & Carstensen, 2003) could also differ on many dimensions, for example: attractiveness, color, age, and sex. Moreover, the faces of the same person displaying different emotions (e.g., anger, happy) differ in the skeletal and muscular movements of the displayed face that could give differential cues for encoding (e.g., Ekman, 1993). One study in support of this idea showed that different parts of the face are more or less optimal to decode different facial expressions (M. L. Smith, Cottrell, Gosselin, & Schyns, 2005). For example, the cheeks are a very distinct feature sufficient to identify a happy face whereas several facial features are needed to decode a negative face. That said, differences, for example, in remembering happy and sad faces could be due to

differences in the efficiency of decoding the configuration of the facial expressions rather than due to the underlying emotion. Similarly, age-related differences in remembering facial expressions could be due to differences in the efficiency of decoding these configurations rather than due to the emotional-tone of the face. This explanation is actually supported by studies that consistently find that accuracy in recognizing emotional faces is reduced in old age (Calder et al., 2003; Malatesta, Izard, Culver, & Nicolich, 1987; Moreno, Borod, Welkowitz, & Alpert, 1993). Thus, it is quite possible, that facial cues rather than the emotional tone of the face promote differential memory for positively- and negatively-toned faces.

In contrast to pictorial materials (e.g., faces), which were being used in contemporary studies more and more due to advances in computer technology, there is a longstanding tradition to use verbal materials (e.g., words) in memory research (e.g., Kausler, 1994). Words, for example, have been used within different memory tasks and paradigms: free recall, recognition, remember/know paradigm, associative learning, and mnemonic methods. Moreover, there is a long history of research investigating word characteristics that may influence memory processes (e.g., Rubin & Friendly, 1986). For example, it is well-known that negative words have a lower frequency in written or spoken text than positive words (e.g., Ortony, Clore, & Foss, 1987) and that words with a high frequency are better remembered in free recall tasks than words with a low frequency (the reverse is true for recognition tasks; Gorman, 1961; Schulman, 1967). There are some other word characteristics that are known to influence memory performance, for example word length, imagery, and emotional intensity (e.g., Rubin & Friendly, 1986).<sup>7</sup> These word characteristics are maybe related to the emotional tone of the to-be-remembered words. Such confounding characteristics might be problematic for the interpretation of research findings. Unfortunately, past research has seldom assessed such characteristics of the to-be-remembered material. Thus, it is generally not the case that positive and negative words have been matched on relevant word characteristics.

Several other kinds of to-be-remembered materials have been used in studies of memory for emotionally-toned material as well, such as advertisements (e.g., Fung & Carstensen, 2003), slide stories (e.g., Kazui et al., 2000), or text passages (Carstensen & Turk-Charles, 1994; Knight et al., 2002). These materials are suited to answer certain well-specified questions. However, these materials are highly complex and involve several levels

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<sup>7</sup>Emotional intensity is defined as either the degree of emotionality from neutral to emotional or the absolute deviation from the neutral midpoint of a bipolar valence dimension.

of connotations (e.g., Bransford, Brown, & Cocking, 1999; Kintsch, 1998). For example, advertisements involve a pictorial and a verbal level that may interact (Fung & Carstensen, 2003), slide stories provide a very specific event (e.g., Burke et al., 1992), and text passages consist of many interacting units of meaning that are prone to reconstructive processes (see Bartlett, 1932). Such kinds of material are important to investigate memory processes under more real life conditions than this is the case for the learning of word lists. In such conditions, however, several interacting processes contribute to the remembrance of the material. Thus, it is difficult to disentangle certain mechanisms involved in the memory process. For a systematic investigation of age-related differences in remembering emotionally-toned material, these materials are not recommended. Instead, easy to manipulate to-be-remembered material should be used.

Second, independent from other confounding variables, the to-be-remembered material in the studies listed in Table 1 was generally not matched in emotional meaning between age groups. One has to admit that almost all normative ratings of words and pictures are based on ratings by young adults (e.g., the IAPS ratings are based on university students). However, the widely-used procedure of using the categorization of young adults to define positive, negative, and neutral material ignores the possibility of age-related or cohort-related differences in the perception of the to-be-remembered material. To say it differently, the associated meaning of the material could change with age or birth cohort. Some stimuli may be more negative or positive for certain age groups than for others as a function of life experience and life time exposure. Thus, age-related or cohort-related changes in the perception of the to-be-remembered materials may also moderate age-related differences in emotional memory.

In fact, the study by Kensinger and colleagues (2002) provides some support for the idea that age-related shifts in the connotation of the to-be-remembered materials moderate age-related differences in the positive-negative disparity. In this study, the significant interactions between valence and age were found by using subjectively-based valence categories. Interactions were not found by using a priori categorization. This implies that a considerable amount of variance in remembering emotionally-toned materials could be explained by inter-individual differences in the perception of the stimuli.

There are only two other studies that have investigated age-related differences in the perception of the emotional tone of the to-be-remembered material. Charles and colleagues (2003) and Denburg and colleagues (2003) asked participants to categorize the to-be-remembered material as positive, neutral, or negative. In both studies, this categorization was

only used to validate the a priori categories rather than to reanalyze the data based on the subjective categorization. The authors stated that the subjective valence categorizations map the a priori valence categories. However, the assessment of the subjective categorizations was probably too coarse to find age-related shifts in stimuli connotation. For example, 'sad' is a negatively-toned word for everyone, but whether it is more or less negative is a different question. Unfortunately, most research in the positive-negative disparity of emotional memory has not verified whether the connotation of the to-be-remembered materials differs between age groups or not.

A third reason for the inconsistency of findings in the studies listed in Table 1 could lie in the fact that the studies differ in the type of memory task(s) applied. Most studies used either a free recall task or a recognition task, but some compared these tasks. The study by Denburg and colleagues (2003), for example, found differential effects for the recall and the recognition task. In the free recall task, participants were better able to recall more negative pictures than positive pictures, whereas in a following forced-choice recognition task participants recognized more positive pictures than negative pictures. This sounds like the word-frequency-paradox mentioned above that high frequent words were better recalled but worse recognized than low frequent words (e.g., Gorman, 1961; Schulman, 1967). It might well be that this is the underlying reason for the differential memory pattern in recall and recognition tasks.

But there is another line of thought that may explain this differential effect in the recall and the recognition task: One intriguing finding in the cognitive literature is that verbalization can induce a processing shift that interferes with the application of non-verbal operations. Schooler and colleagues reported several studies indicating that talking about faces impairs recognition memory for them, a phenomenon they termed *verbal overshadowing effect* (e.g., Dodson, Johnson, & Schooler, 1997; Fallshore & Schooler, 1995; Schooler & Engstler-Schooler, 1990). This effect would indicate that it is not appropriate to conduct a picture recall task (that is a verbal description of the to-be-remembered material) previous to a picture recognition task (that is a non-verbal operation). The verbalization in the picture recall task could interfere with the picture recognition task that should lead to memory impairments for the described pictures. Moreover, verbalization of pictures not only interferes with recognition of that picture but also with the recognition of other pictures (C. Brown & Lloyd-Jones, 2002; Dodson et al., 1997; Fallshore & Schooler, 1995). Thus, the verbal overshadowing phenomenon would predict that pictures superiorly recalled would be

less often recognized in a following recognition task. This prediction actually reflects the differential pattern found by Denburg and colleagues (2003).

In contrast to the disruptive effects that verbalization has on non-verbalizable cognitions, tasks that rely on more verbal processes (e.g., word recall) have proven to be relatively immune to the impact of verbalization. For example, whereas verbalizing the appearance of a robber's face impairs memory for the face, verbalizing what the robber said does not impair memory for this statement (e.g., Fallshore & Schooler, 1995).

In one study, Memon and Bartlett (2002) investigated age differences in the verbal overshadowing effect. They found no evidence for age-related differences in the overall verbal overshadowing effect. Nevertheless, their findings suggest that verbalization can affect processes and strategies involved in recognition memory in ways that might vary with age. For example, older adults have difficulties in the ability to simply name pictures of objects. A meta-analysis across several studies showed that older adults make more errors in naming pictures than young or middle-aged adults do (Feyereisen, 1997).

The verbal overshadowing effect is only relevant for studies that (a) used non-verbal to-be-remembered materials (e.g., pictures, faces), (b) applied a free recall and a recognition task within the same sample for the same material, and (c) applied the free recall task first. This is the case for the studies by Charles and colleagues (2003) and Denburg and colleagues (2004). Aside from the very special case of verbal overshadowing, there is no theoretical reason available to expect a different memory pattern for the positive-negative disparity in a free recall and a recognition task. Consistent with this, the empirical evidence from the reviewed studies does not reveal a different memory pattern for free recall or recognition tasks.

Fourth, interference effects between memory tasks could qualify the findings. Most studies investigating age-related differences in the positive-negative disparity of emotional memory applied two or more different memory tasks within the same sample. Some studies used different memory retrieval intervals for the same material presented once (Charles et al., 2003; Denburg et al., 2003; Knight et al., 2002; Leigland et al., 2004); other studies used different memory tasks for different to-be-remembered materials (Kensinger et al., 2002; Leigland et al., 2004). This procedure of multiple memory tasks could give rise to interference effects for the second or third memory task. The previously mentioned verbal overshadowing phenomenon is such an interference effect.

One way to deal with potential interference effects between tasks could be to counterbalance the order of the tasks. Unfortunately, basically all studies did not manipulate

the order of the memory tasks. One exception is Study 2 by Charles and colleagues (2003). In this study, a free recall and recognition task for the same set of pictures was counterbalanced between subjects. And indeed, the authors found a significant effect of order on memory performance: When the recall task was administered after the recognition task, both young and older adults recalled more items. Unfortunately, the authors did not report memory performance for positive, negative, and neutral pictures in both ordering conditions. Thus, the question of whether ordering effects of tasks influence memory for emotionally-toned material is still open. Nevertheless, the main effect of tasks ordering highlights the difficulties in interpreting findings from studies with different memory tasks within one sample.

A final potential source of inconsistent findings is that the applied retention intervals between encoding and retrieval differed tremendously between studies: (a) immediately (Kensinger et al., 2002; Knight et al., 2002; Leigland et al., 2004), (b) 10 to 15 minutes (Charles et al., 2002; Mather & Carstensen, 2003), (c) 30 minutes (Leigland et al., 2004), (d) 24 hours (Denburg et al., 2003), (e) 14 days (Comblain et al., 2004), and (f) 8 months (Denburg et al., 2003). None of these studies reported a rationale for the applied retention intervals.

There is some evidence that the enhancement of memory for emotional material in comparison to neutral material increases with time (Kleinsmith & Kaplan, 1963, 1964). There are also some initial proposals that negatively-toned materials are forgotten faster than positively-toned materials (see section 2.3.4 *Long-Term Consolidation*). Different forgetting curves for positively- and negatively-toned materials could generate inconsistent results across studies that have used different retention intervals. However, there is no systematic investigation of different retention intervals for positively- and negatively-toned materials available. Thus, up to now, the effects of different retention intervals on the positive-negative disparity of emotional memory are speculative.

Overall, the inconsistent findings could be due to a multitude of causes. Methodological flaws seem to be one of the main contributors to the heterogeneity of findings. In order to avoid more findings that are ambiguous, future research should focus on at least five points. These points include (a) systematic matching of to-be-remembered material on memory-relevant characteristics (e.g., word length), (b) systematic ratings of valence by young and older adults to control for possible age- and cohort-related differences in perceiving the emotional tone of the to-be-remembered material, (c) systematic comparison of performance within as well as between memory tasks, (d) examination of between-subjects as well as within-subjects effects, and (e) the systematic investigation of

different retention intervals. These design aspects may be used to examine more carefully ideas about processes underlying memory enhancement effects and age differences in the positive-negative disparity of emotional memory.

### **2.3 PROPOSALS FOR AGE-RELATED DIFFERENCES IN THE POSITIVE-NEGATIVE DISPARITY OF EMOTIONAL MEMORY**

In the previous section (see section 2.2 *Age-related Differences in Remembering Emotional Material: Empirical Findings from Experimental Approaches*), empirical experiments investigating age-related differences in remembering emotionally-toned material were reviewed. The review revealed two major conclusions: First, the general enhancement of memory by emotion seems to be well-preserved into old age. Second, findings are inconsistent with regards to age-related differences in the positive-negative disparity of emotional memory. Potential reasons for these inconsistent findings across and within studies were discussed (see section 2.2.4 *Potential Reasons for Inconsistent Findings*).

In this section, I discuss proposals for age-related differences in remembering emotionally-toned material. To do this, I focus on potential mechanisms that contribute to the general enhancement of memory by emotion and to the positive-negative disparity of emotional memory. Five key mechanisms have been proposed in this context (Christianson, 1992b; Heuer & Reisberg, 1992; Leichtman, Ceci, & Ornstein, 1992; Reisberg & Heuer, 2003): (a) differential allocation of processing resources to emotional events, (b) differential arousal levels accompanying emotional events, (c) post-encoding processes, namely long-term consolidation of emotional information, (d) emotion regulation, and (e) mood-congruent memory and mood-dependent retrieval. These proposed mechanisms differ in their specificity (i.e., level of analysis) from specific attention processes to wide-ranging emotion regulation processes. The mechanisms differ also in their relevance for the general enhancement of memory by emotion and their relevance for the positive-negative disparity of emotional memory. Basically all mechanisms are associated with age-related changes that may influence age-related differences in remembering emotionally-toned material. However, empirical investigations of age-related differences in these mechanisms in the context of emotional memory are for the most part missing. Thus, the impact of these mechanisms on age-related differences in emotional memory are still speculative.



### 2.3.1 Attention and Processing Priority

Human beings are constantly bombarded with a vast amount of information, generated by external as well as internal sources. Clearly, it is impossible to deal successfully with all this information (e.g., Shiffrin, 1988). An organism needs a selection mechanism that selects highly relevant information for the organism's current needs and wishes (e.g., Lang et al., 1997). Attention is such a selection mechanism that allows people to focus on high-priority information and to filter out or attenuate material of secondary importance (e.g., Pashler, 1998). In this view, attention involves procedures to select and evaluate information that are pertinent for our lives, goals, and values or for lives of people we care about (e.g., C. A., Smith, & Kirby, 2001). When the outcome of this ongoing scan signifies personal relevance, the organism prepares adequate action tendencies (Frijda, 1986). And emotional events are typically carrier of such relevant information. According to a motivational view of emotion, emotions have evolved to deal with fundamental life tasks that either promote or threaten physical survival. For the organism, emotional information, whether pleasant (e.g., food) or unpleasant (e.g., snakes), is most often indicative of situations that have a greater impact for reproductive success, well-being, and survival than neutral information does. Thus, emotions should be tightly linked to attention processes.

In the literature on attention, Posner and Peterson (1990) distinguish three major components of attention, namely *alerting*, *orienting*, and *executive control*. Alerting refers to nonselective modulation of attention that enhances performance on sensory processing tasks (e.g., better performance after a warning cue). The orienting component is responsible for the shifting of attention to a new location. The executive control component is involved in resolving conflicting demands on attention and inhibiting dominant response tendencies. These distinctions are important for the focus of this section, that is, the impact of attention and processing prioritization on the operation of emotion on memory processes.

The literature on the operation of emotion on attention processes can be divided in two major brunches: First, there is research investigating the influence of emotion on orienting and shifting attention. For example, studies investigating the differential impact of emotion on attention for central and peripheral details belong to this line of research (see *1.2.2 Experimental Approaches to Investigate Emotional Memory*). Second, there are studies investigating the effect of emotion on executive processes. The majority of studies that are interested in the cognitive consequences of emotional states is located in this line of research (see *1.3.1 Differential Processing of Positive and Negative Information*).

In the literature on the influence of emotion on shifting attention, the findings do not provide a clear pattern. On the one hand, there is considerable research on the Easterbrook hypothesis. The Easterbrook hypothesis states that emotional arousal triggers attention narrowing for central aspects of the emotional event. In the literature on emotional memory, some studies provide support for this proposal: Whereas memory for central aspects is enhanced, memory for peripheral aspects is diminished (e.g., Burke et al., 1992; Christianson & Loftus, 1991; Safer, Christianson, Autry, & Österlund, 1998; Wessel & Merckelbach, 1997, 1998). There are, however, some studies that do not find a memory advantage for central details (e.g., Libkuman et al., 1999; Wessel et al., 2000). Instead, these studies find a general enhancement for central and peripheral details by the variation of the emotional tone. On the other hand, there is a growing literature on the impact of emotion on shifting attention to stimuli in the periphery of the visual field. These studies have failed to demonstrate effects of emotional stimuli on orienting or shifting attention (Fox, 1994; Gronau, Cohen, & Ben-Shakhar, 2003; M. White, 1996; but see Öhman et al., 2001). For example, in a series of studies, Gronau and colleagues asked participants to perform a task that was presented in the center of the screen (e.g., naming the color of an object as fast as possible). In the periphery of the screen, words and objects were presented that were unrelated to the main task. Participants were instructed to ignore these surrounding stimuli. The findings did not reveal any support for the idea that emotional information triggers an automatic shift in attention to the emotional information. Taken together, the influence of emotion on shifting attention to the location of the emotional information has not consistently been shown. Quite the opposite, the majority of studies has not find such an effect.

In the literature on the influence of emotion on executive processes, in contrast, the findings are more consistent. There is considerable evidence that emotional stimuli produce interference effects when they are competing with other stimuli for cognitive resources (e.g., A. K. Anderson, 2003; Buodo et al., 2002; Gronau et al., 2003; Harris & Pashler, 2004; Pratto & John, 1991). Harris and Pashler, for example, find that emotional words slowed reaction times for a speeded judgment about whether two digits are equal. The interference effects produced by emotional information are thought to be signifying a relative automatic and dominant processing of emotional information. The automatic prioritization of emotion schemas interferes with other competing processes.

In this line of research, a processing priority for negative over positive information has been shown (Charles et al., 2003; Fiske, 1980; Klinger et al., 1980; Ohira et al., 1997; Pratto & John, 1991; M. White, 1996). As discussed above (see *1.3.1 Differential Processing*

*of Positive and Negative Information*), evidence for emotion-based processing prioritization for negative information is particularly provided by the emotional Stroop task (Pratto & John, 1991; M. White, 1996). In the emotional Stroop task, negative words produced longer response latencies than positive words signifying more interference in the competing task (i.e., reaction time task) for negative than for positive words. Thus, these findings indicate processing prioritization for negative information.

The study by Mather and Carstensen (2003) provided initial evidence for age-related differences in the impact of emotion on attention processes. The authors investigated reaction times for a dot probe displayed in the location of a positive, negative, or neutral face (i.e., a dot-probe task). In each trial, a neutral and an emotional face were presented simultaneously. Young adults did not show any significant differences in responding to a dot probe following a positive, negative, or neutral face. However, older adults were slower to respond to a dot probe displayed in the location of a negative face than in the location of a neutral or positive face. The authors interpreted this pattern as evidence for a positivity effect in older adults. In particular, older adults pay more attention to positive information; therefore, older adults were faster to respond to stimuli following positive faces. An alternative interpretation would be that the processing of negative information demands more resources reducing the resources available to deal with competing tasks such as the response on a dot probe. This interpretation is in line with research on age-related differences in the emotional Stroop task. Wurm and colleagues (Wurm, Labouvie-Vief, Aycock, Rebucal, & Koch, 2004) find that older adults responses to high-arousing words were slower than to mid- and low-arousing words. In contrast, young adults did not reveal any differences in reaction times between high- and low-arousing words. This pattern that high-arousing words produce longer reaction times in older adults is consistent with the finding by Mather and Carstensen that angry and sad faces produce slower responses in older adults.

Taken together, attention plays a crucial role in the processing of emotional information, especially in the executive component of attention (Posner & Peterson, 1990). Emotional information interferes with the processing of a competing task, that is, emotional information is prioritized in the processing of information. There is some evidence that processing prioritization is stronger for negative than for positive information (Pratto & John, 1991; M. White, 1996). Moreover, there is some evidence that older adults might be more affected by emotion-based processing prioritization than younger adults (Mather & Carstensen, 2003; Wurm et al., 2004). However, more research is needed to settle down questions about age-related differences in the processing of emotional information.

### 2.3.2 Arousal

In an extensive research program, Lang and colleagues have examined the experiential, behavioral, and physiological responses to affective pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Bradley et al., 1992, 2001; Keil et al., 2002; Lang, 1995; Lang, Greenwald, Bradley, & Hamm, 1993). The evidence from this research program suggests that responses to affective pictures form two factors: valence and arousal. Whereas valence varies from pleasant to unpleasant feelings, arousal varies from low activation to high activation. Some indicators such as experiences of pleasure and displeasure, facial expressions, the startle probe, and heart rate, vary with the valence of the picture. In contrast, interest ratings, voluntary exposure, skin conductance, the magnitude of initial heart rate deceleration after picture onset, the P300 in the event-related potential, and activation in the occipital cortex in functional magnetic resonance imaging scans vary with the arousal level of pictures. Moreover, in a study by Bradley and colleagues (1992), memory for emotionally-toned pictures was primarily driven by arousal than by valence.

There is considerable evidence for the crucial role of arousal in enhancing memory (for reviews see Cahill & McGaugh, 1996, 1998; McGaugh, 2003). Cahill and colleagues (Cahill, Prins, Weber, & McGaugh, 1994), for example, investigated the effect of arousal by injecting participants with propranolol, a beta-adrenergic blocker chosen to diminish the bodily arousal effect of emotion. If the enhancement of memory by emotion depends to some degree on the arousal component that accompanies the emotional reaction, the beta-blocker should reduce or eliminate the enhancement of memory. If the memory advantage for emotional material, in contrast, depends on other factors, it is unlikely that the beta-blocker should have an effect. The findings emphasize the important role of arousal in remembering emotional material. The injection of propranolol reduces the memory advantage for emotional material.

Arousal has often been linked to negative aspect of our lives such as stress, anxiety, and fear. Nevertheless, arousal can also accompany positive aspects of our lives (e.g., sexual arousal). Consistent with the idea of a general memory advantage for high-arousing stimuli, some studies found better memory for extremely unpleasant and extremely pleasant stimuli than for mildly unpleasant and mildly pleasant stimuli (e.g., Bradley et al., 1992; Buodo et al., 2002). Thus, the *emotional intensity* of the stimuli (irrespective of the emotional tone)

was predictive of later recall.<sup>8</sup> In this context, an open question is, however, whether arousal for negative information and arousal for positive information involve the same processes and rely on the same neural substrates (Foote, 2000). Thus, the question is whether arousal due to positive information differs from arousal due to negative information. Until now, there is no concluding answer to this question.

Regarding age-related differences in arousal, there is some evidence for an age-related decline in physiological reactivity to emotional information (e.g., Labouvie-Vief, Lumley, Jain, & Heinze, 2003; Levenson, Carstensen, Friesen, & Ekman, 1991; Levenson, Carstensen, & Gottman, 1994; Tsai, Levenson, & Carstensen, 2000; but see Kunzmann & Grühn, 2005). In particular, the cardiovascular system (e.g., heart rate) is less responding in older adults than in young adults (Levenson et al., 1991, 1994). This might be evidence for an age-related decline in the capacity to experience physiologically strong arousal. If arousal plays a crucial role in the enhancement of memory by emotion, and if arousal is generally reduced in older adults, the general memory enhancement effect of emotion might be as well reduced in older adults. In contrast, the findings by Wurm and colleagues (2004) reveal a stronger effect of high-arousing stimuli on the processing of emotional information in older adults than low-arousing stimuli. This finding signifies that older adults' processing was overwhelmed by high-arousing stimuli. Thus, it might well be that the enhancement effect of memory by emotion is even stronger in older adults under high-arousing conditions. Nevertheless, until now, no study has systematically manipulated the to-be-remembered material to investigate age-related differences in emotional memory for different levels of arousal.

### 2.3.3 Emotion Regulation

Emotions typically elicit a coordinated set of behavioral, experiential, and physiological response tendencies (e.g., R. J. Davidson, Goldsmith, & Scherer, 2003; Frijda, 1986; Scherer, 2001). These response tendencies often realize appropriate reactions to demands of our varying environments (Tooby & Cosmides, 1990). Sometimes, however, emotional responses can be misleading, especially in contemporary physical and social environments that differ tremendously from those that shaped our emotions over millennia. In

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<sup>8</sup> In the literature on emotion, the terms arousal, emotionality, and emotional intensity are not clearly defined. Moreover, these terms are often used interchangeably. In this dissertation, I use the term *arousal* to refer to a rating of excitement, stimulation, or tension. *Emotionality* is used to refer to a rating of how emotional versus neutral an item is. And *emotional intensity* is used to refer to a derived measure of valence ratings, that is, the absolute deviation from the neutral midpoint of a bipolar valence scale. Obviously, these dimensions should show a high degree of overlap. However, I am not aware of any study that has systematically compared these dimensions.

such times, the emotional response may be ill-matched to the actual requirements of the situation and we try to down-regulate our emotional response. What effects might emotion regulation have for cognitive processes? There is a growing literature suggesting that nearly all kinds of self-regulation deplete mental resources (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven, Tice, & Baumeister, 1998). For example, participants who were asked to regulate their emotions solved fewer anagram problems than control participants (Baumeister et al., 1998). Similarly, Richards and Gross (2000) investigated the cognitive consequences of reappraisal and suppression on memory performance. Reappraisal and suppression are two commonly used strategies for down-regulating emotions (Gross, 1998, 1999, 2002). Reappraisal involves a cognitive change in the way the situation is constructed before the emotional response tendencies have become fully activated. The typical reappraisal strategy is to consider an emotional event from a non-emotional perspective. Suppression, in contrast, involves strategies we use once an emotion is on the way. The usual suppression strategy is to actively inhibit all expressive signs of the emotion.

Richards and Gross (2000) expected to find memory decrements for the effortful suppression strategy and only small or no such decrements for the relative effortless reappraisal strategy. To investigate these expectations, the authors presented participants either a film clip (Study 1) or medical slides (Study 2) that elicit negative emotions. Afterwards, participants were asked to perform a memory task. The findings are consistent with expectation: Compared with control participants, participants who were asked to suppress their emotional response during presentation showed reduced memory for details in the film clip and in the medical slides. In contrast, participants who were asked to watch the slides with the detached interest of a medical professional (reappraise) showed no significant impairments in their memory performance. These findings suggest that whereas suppression is cognitively costly, reappraisal is not.

Regarding the enhancement of memory by emotion, the findings by Richards and Gross (2000) suggest that the cognitive costs of emotion regulation might counteract the beneficial effect of emotion on memory performance. This leads to the intriguing speculation that with increasing intensity of the emotional information, volitional emotion regulation strategies are more and more likely that offset the memory enhancing effect of the emotional tone variation. Thus, the impact of the emotional tone on memory performance might flatten or even drop with increasing intensity. Unfortunately, there is no study available to my knowledge that has systematically investigated this idea in the context of memory for emotionally-toned material. Moreover, Richards and Gross did not differentiate the to-be-

remembered material into emotional and neutral information. Thus, it is an open question in their study of whether emotion regulation reduces memory per se or whether memory for emotional and neutral material was differentially affected by emotion regulation efforts.

Regarding age-related differences in emotion regulation, there is a lifespan proposal based on *socioemotional selectivity theory* (SST; Carstensen, 1993, 1995; Carstensen & Charles, 1998; Carstensen et al., 1999). SST posits that persons are motivated to pursue goals for three basic reasons: (a) knowledge acquisition, (b) development and maintenance of self-worth, and (c) emotion regulation. Depending on the phase in one's life, the weighing of the three motives differs fundamentally. SST contends that humans are aware of their time left in life, consciously or unconsciously, and that this time perspective structures motivations and goals. Carstensen argues that as people approach the end of their lives more weight is given to the selection of goals that are related to emotion and emotion regulation. Given that the end of life is typically associated with chronological age, older adults, in contrast to younger adults, are more likely to emphasize the emotional aspects of goals.

Several studies, especially in the domain of social relationships, provide empirical support for SST (e.g., Carstensen & Fredrickson, 1998; Carstensen et al., 1999; Fredrickson & Carstensen, 1990; Wagner, Schütze, & Lang, 1999). Young people, for example, value the knowledge-acquisition functions of social relationships more, but as people grow older, they move toward valuing the emotional and self-enhancing rewards of social relationships more highly. Older adults make social choices increasingly selective with emotional rewards in mind, and with less emphasis on the novelty and information stimulation of new social relationships.

Thus, SST predicts that older adults' emphasis on emotional goals enhances emotion regulation with age (e.g., Carstensen & Charles, 2003; Charles et al., 2003). In this framework, emotion regulation is conceptualized as the maintenance of positive affect and the minimization or avoidance of negative affect. Several self-report studies have supported the view of enhanced emotion regulation with age, that is, older adults report better emotion regulation capacities than young adults (Carstensen et al., 2000; Charles, Reynolds, & Gatz, 2001; Lawton, Kleban, & Dean, 1993). However, findings from self-assessments of knowledge and skills can be misleading with regards to actual knowledge and skills (for a review see Dunning, Heath, & Suls, 2004). Indeed, one study by Kunzmann, Kupperbusch, and Levenson (2005) did not find evidence for improvements in emotion regulation capacities with age. They investigated age-related differences in the ability to suppress or to amplify emotional reactions to film clips. To do this, the authors measured the emotional

reaction of young and older adults on a behavioral (i.e., facial expression), physiological, and self-report level. On all three levels, no age-related differences in the ability to suppress or to amplify emotional reactions were apparent. Thus, older adults were not better in emotion regulation than young adults. However, this is also good news. In contrast to the cognitive domain in which age-related loss are apparent, the capacity of emotion regulation seems to be well-preserved with age.

To the extent that emotion and emotion regulation are reflected in cognitive processes, younger and older adults probably differ in the processing of emotionally relevant information. Charles and colleagues (2003) stress the point that memory is not passive retrieval of information, but an active process in which goals (at least partly) influence the elaboration and construction of information (see also Higgins, 1987; Higgins & Tykocinski, 1994). Conceptualizing memory as a self-regulatory process, in which retrieved information influences well-being, Charles and colleagues propose that the enhanced emphasis of older adults on emotion regulation should have an effect on the encoding, storage, and retrieval of information. In particular, Charles and colleagues predict that older adults remember positive material better than negative material. Thus, if memory is associated with self-regulatory processes, and if positive information have a greater salience for older adults, memory should be better for positive than for negative material in old age.

This theoretical extension of SST to memory processes is, however, a relatively broad theoretical statement. Special mechanisms are not explicitly addressed in the model. Moreover, the general idea of a positivity effect in older adults' memory depends on the assumption that older adults show improved emotion regulation capacities that lead older adults to prioritize positive information over negative information. The empirical evidence for this assumption is, however, still missing. Nevertheless, many studies investigating age-related differences in emotional memory used SST as a theoretical framework.

### **2.3.4 Long-Term Consolidation**

In one of the earliest studies, Kleinsmith and Kaplan (1963, 1964) found that neutral items were better recalled than emotional items when tested immediately after presentation. Emotional items, in contrast, were better recalled than neutral items with delayed testing. This finding gave rise to the idea that the enhancement of memory by emotion magnifies with increasing retention interval. In the meantime, several studies have supported the long-term enhancement effect for emotional material (e.g., Paré, Collins, & Pelletier, 2002; Quevedo et al., 2003). Consolidation processes are most likely involved, in which memories for



emotional events become more permanent and more resistant to loss (Hamann, 2001). Such consolidation processes require a period to operate, meaning that the effect of emotion on memory more gradually increase with time (Cahill & McGaugh, 1996, 1998).

Considering long-term memory differences between positive and negative events, there is some evidence that positive personal events are better remembered than negative events. Walker and colleagues (1997), for example, asked participants to recall certain events from their diaries 3 months, 1 year, or 4.5 years after collection of personal events. The results revealed better memory for positive events after longer retention intervals. This finding is consistent with the *Mobilization-Minimization Hypothesis* (Taylor, 1991) that negative information undergoes greater minimization than positive information after the event. Unfortunately, no laboratory study has systematically investigated the effect of different retention intervals for positive and negative material.

From a neuroanatomical viewpoint, the amygdala is considered to play a crucial role in emotionally influenced memory. Several neuroimaging studies suggest that the amygdala plays a fundamental role in encoding and consolidation processes (Hamann, 2001). On the one hand, amygdala activity at encoding is predictive of subsequent memory performance for emotionally-toned material (Cahill et al., 1996). On the other hand, several studies have supported a modulating function of the amygdala in long-term memory consolidation (e.g., Maren, 1999). The view of the amygdala as important basis for the processing of emotional information is also strengthened by lesion studies. Patients with amygdala lesions often show deficits in the perception and memory for emotional stimuli (e.g., A. K. Anderson & Phelps, 2001; but see Phelps, LaBar, & Spencer, 1997). These results suggest that both factors, encoding and consolidation processes are probably involved in modulating the enhancement effect for emotional stimuli (Christianson, 1992a, 1992b; Hamann, 2001).

Aging is related to several changes in brain activity and structure that may influence long-term memory for emotionally toned material. On the one hand, brain regions associated with emotional processing (i.e., prefrontal cortex, amygdala, anterior cingulate) are less deteriorated with age than other regions (C. D. Smith et al., 1999). This might indicate that the enhancement of memory by emotion is relatively well-preserved in healthy older adults. Additional evidence for the role of the amygdala in the enhancement of memory by emotion is provided by a study with Alzheimer's disease patients (Mori et al., 1999). In this study, memory about the Kobe earthquake was higher correlated with the volume of the amygdala than with the volume of the hippocampus in Alzheimer's disease patients (Mori et al., 1999), indicating that the enhancement of memory by emotion is related to the shrinkage of the

amygdala. On the other hand, older adults, in contrast to younger adults, showed less activation in the amygdala when perceiving emotional stimuli (Iidaka et al., 2002). A neuroimaging study by Mather and colleagues (2004) supported this finding for negative pictures. In their study, young and older adults were asked to rate the emotional arousal of 64 negative, 64 positive, and 64 neutral pictures. For negative pictures, older adults showed less activation in the amygdala than young adults. In contrast, both age groups showed similar activation levels in the amygdala for positive pictures. The authors interpret their findings as suggesting that older adults' processing of positive information is well-preserved whereas the processing of negative material is diminished or down-regulated. Consequentially, memory for positive material is thought to be well-preserved in older adults whereas memory for negative material is not. However, the authors did not assess memory performance for the emotionally-toned pictures and could not test this prediction (or at least they did not report the memory performance).

Regarding the behavioral studies investigating age-related differences in the positive-negative disparity, the empirical evidence for different retention intervals is rather consistent. Three studies found no empirical evidence for an Age x Time x Valence interaction (Denburg et al., 2003; Knight et al., 2002; Leigland et al., 2004), that is, there was no evidence that remembering positive and negative material differed for young and older adults with different retention intervals. Consistent with the theoretical proposal by Taylor (1991), two studies revealed a positivity shift that both age groups remembered more positive than negative stimuli in the delayed than in the immediate memory task (Knight et al., 2002; Leigland et al., 2004). In contrast, Charles and colleagues (2003) found in Study I a different memory pattern for young and older adults in the immediate and delayed memory task. In particular, young adults recognized more negative than positive pictures whereas older adults recognized positive and negative pictures equally well. This might be evidence for a negativity shift in young adults' memory. However, the authors used different memory tasks for the immediate (i.e., free recall) and the delayed (i.e., recognition) memory task making it rather difficult to interpret their findings.

In sum, there is some evidence that the effect of emotion on memory performance increases with increasing retention interval (Kleinsmith and Kaplan, 1963, 1964; Paré, Collins, & Pelletier, 2002; Quevedo et al., 2003). Regarding long-term memory differences for positive and negative material, there is an initial proposal that positive material is better remembered than negative material with longer retention intervals (Taylor, 1991). There is also initial empirical support for this proposal (Knight et al., 2002; Leigland et al., 2004;

Walker et al., 1997). Despite the theoretical proposal from a neuroimaging study (Mather et al., 2004), there is no consistent evidence that the positivity effect in older adults' memory increases with increasing retention interval.

### **2.3.5 Mood-Congruent Memory and Mood-Dependent Retrieval**

Are events that have been encoded in a certain state of affect or mood (e.g., sadness) more easily retrievable in the same state than in a different one (e.g., happiness)? Moreover, is to-be-remembered material with a certain emotional tone (e.g., negative) more easily remembered when the person is in the same state rather than a different one? These and similar questions were primarily addressed by the experimental work of Gordon Bower (e.g., Bower, 1981; Bower & Forgas, 2000, 2001; Bower & Gilligan, 1979; Bower, Gilligan, & Monteiro, 1981; Bower & Mayer, 1985; Bower, Monteiro, & Gilligan, 1978). The basic idea is that we not only store sensory information about an event but also emotional information. Our current mood will affect the way we store our memories and the way we try to retrieve these memories. When we are in a happy mood, happy memories are most easily available to us (and vice versa). The emotional information functions as an additional cue for the retrieval process. In this framework, *mood-congruent memory* occurs where current mood helps to recall mood-congruent material, regardless of our mood at the time the material was stored. Thus when we are happy, we are more likely to remember happy events. *Mood-dependent retrieval* occurs where the congruence of current mood with the mood at the time of memory storage helps recall of that memory. When we are happy, we are more likely to remember other times when we were happy.

Despite some inconsistent findings in the 1980ies (Bower & Mayer, 1989), reliable effects of mood-congruent and mood-dependent retrieval have been observed under conditions in which participants experience a strong mood rather than a faint mood and in which participants generate the cues or memories themselves rather than given cues or memories (Eich, 2004; Forgas, 1995). Mood-congruent memory effects have also been observed with different psychiatric groups: Depressed individuals, for example, remember negative material better than positive material (Matt et al., 1992; Watkins Mathews, Williamson, & Fuller, 1992). Moreover, consistent with mood-congruent memory effects, spider-phobics remember phobia-related material better than neutral material (Wessel & Merckelbach, 1997, 1998). Moreover, individual differences in personality seem to play an important part in mood-congruent memory (Bower & Forgas, 2000; Smith & Petty, 1995) and probably also in mood dependent memory (Eich & Macaulay, 2000).

Regarding age-related differences in mood-congruent memory, two studies found that mood-congruent memory effects are well-preserved in older adults (Knight et al., 2002; Yang, J. A. & Rehm, 1993). Thus, it might well be that age-related differences in current mood affect systematically memory for emotionally-toned material. For example, if older adults experience on average more positive affect than young adults, older adults are may be more likely to learn and to retrieve positive information than negative information. In this context, age-related differences in trait affect or current mood might be an alternative explanation for age-related differences in the positive-negative disparity of emotional memory. This explanation depends on the assumption that age-related differences in positive and negative affect exist. The empirical evidence for age-related differences in positive and negative trait affect is, however, inconsistent. On the one hand, there is some evidence for an age-related decline in negative affect and mostly constant values for positive affect across age groups. This evidence stems from cross-sectional (Barrick, Hutchinson, & Deckers, 1989; Carstensen et al., 2000; Costa, McCrae, & Zonderman, 1987; Gross et al., 1997; Isaacowitz & Smith, 2000; Lawton et al., 1993; Lawton, Kleban, Rajagopal, & Dean, 1992) and longitudinal studies (Kunzmann, Little, & Smith, 2000; Stacey & Gatz, 1991). On the other hand, there are also four studies that did not reveal a consistent association between chronological age and negative affect (Diener & Suh, 1997; Levine & Bluck, 1997; Malatesta & Kalno, 1984; Mroczek & Kolarz, 1998). Moreover, there are three studies showing an age-related decline in positive affect in cross-sectional (Costa et al., 1987; Diener & Suh, 1997) and longitudinal research (Stacey & Gatz, 1991). Taken together, a clear pattern for age-related differences in positive and negative affect is not apparent in the literature. Some inconsistencies might depend on different assessment methods for affect. Nevertheless, if older adults differ from young adults in current mood or in trait affect, this might explain age-related differences in remembering emotionally-toned information.

### **2.3.6 Summary**

The research about different mechanisms involved in the enhancement of memory by emotion suggests a complex interplay between mechanisms rather than one fundamental mechanism. Emotional events are certainly associated with higher levels of arousal, but involve as well different types of processes: attentional processes, emotion regulation processes, and long-term consolidation processes. Moreover, person characteristics such as current mood or trait affect might influence the encoding and retrieval of emotional information. As discussed above, all these mechanisms might have an impact on memory for

emotionally-toned material. However, the relative contribution of each mechanism is not known. Moreover, an open question is whether different mechanisms interact in a linear or non-linear fashion. For example, it might well be that with increasing arousal of the emotionally-toned stimuli, emotion regulation capacities are more and more relevant resulting in a dampening of memory for high-arousing stimuli rather than a linear increase.

Regarding age-related differences in memory for emotionally-toned material, this opens the door for several speculations about processes that may influence emotional memory in old age.