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Differential Effects of Aging on Memory for Content and Context: A Meta-Analysis

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The authors reviewed the evidence of age differences in episodic memory for content of a message and the context associated with it. Specifically, the authors tested a hypothesis that memory for context is more vulnerable to aging than memory for content. In addition, the authors inquired whether effort at encoding and retrieval and type of stimulus material moderate the magnitude of age differences in both memory domains. The results of the meta-analysis of 46 studies confirmed the main hypothesis: Age differences in context memory are reliably greater than those in memory for content. Tasks that required greater effort during retrieval yielded larger age differences in content but not in context memory. The greatest magnitude of age differences in context memory was observed for those contextual features that were more likely to have been encoded independently from content. Possible mechanisms that may underlie age differences in context memory–attentional deficit, reduced working memory capacity, and failure of inhibitory processing are discussed.

Age-related differences in memory are ubiquitous, and, as a rule, old age is associated with reduction in performance (Verhaeghen, Marcoen, & Goossens, 1993). The magnitude of these differences, however, varies across the types of memory. For example, mnestic functions assessed by direct (explicit) tests are considerably more vulnerable to the effects of aging than those measured by indirect methods such as repetition priming (La Voie & Light, 1994). Even within the explicit memory domain there is no uniformity: Age-related declines in recognition are smaller than in recall (Craik & McDowd, 1987). To explain selective age-related differences in memory, some authors have focused on the relationship between the content of the message and the context in which it was presented (Craik & Jennings, 1992; Light, 1991). Although recollection of context is not necessary for explicit recollection of content, availability of contextual cues improves recall (Graf & Mandler, 1984). Moreover, it is widely believed that the process of retrieval is facilitated by reinstatement of the elements of encoding context at the time of test (Smith, Glenberg, & Bjork, 1978; Tulving, 1983). Thus, if age differences in memory are proportional to the degree of contextual involvement in retrieval, age-related declines in memory for context itself should exceed the differences observed in memory for content.

Age differences in memory for context appear quite consistent. In comparison with their young counterparts, older people experience difficulties in remembering the source of information (e.g., McIntyre & Craik, 1987). They also evidence problems in remembering whether actions were imagined or performed (G. Cohen & Faulkner, 1989), whether words were thought or uttered (Hashtroudi, Johnson, & Chrosniak, 1989), and whether words were read or mentally generated (Rabinowitz, 1989). Older adults are not as good as the young at recalling the modality in which information was presented (Light, La Voie, Valencia-Laver, Albertson-Owens, & Mead, 1992; McIntyre & Craik, 1987), at identifying the presenter of stimulus items (e.g., Hashtroudi et al., 1989), or at identifying the sex of the presenter (Kausler & Puckett, 1981b). Older adults also tend to forget specific contextual details such as the case format of stimulus text (Kausler & Puckett, 1980), the color of stimulus material (Park & Puglisi, 1985), or the spatial location of items (Park, Puglisi, & Lutz, 1982).

The question is, however, not whether older adults are less adept in remembering contextual features than young adults, but whether these differences are disproportionately greater than age-associated impairment in memory for content. There is evidence that, under certain conditions, this is indeed the case. Some examples of such conditions are when items are presented in blocks (Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991) or when source amnesia (i.e., the failure to recall source information after correctly recalling a fact) is considered (Craik, Morris, Morris, & Loewen, 1990; Spencer & Raz, 1994). In other studies, however, differential age effects on memory for context are relatively small (Denney, Miller, Dew, & Levav, 1991; Gregory, Mergler, Durso, & Zandi, 1988; Mitchell, Hunt, & Schmitt, 1986).

Neuropsychological findings indicate that content and context memory may be sustained by relatively autonomous brain systems, thus suggesting that dissociation between these two mnemonic functions may have neural underpinnings. Specifically, the prefrontal cortex may play a critical role in memory context retrieval and only a minor one in recollection of memory content, whereas medial temporal and diencephalic structures are probably important for all explicit memory tasks (Schacter, 1987;

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Squire, 1987). This proposition is supported by investigations of amnesic patients with and without frontal lobe lesions (Janowsky, Shimamura, & Squire, 1989; McAndrews & Milner, 1991; Schacter, Harbluk, & McLachlan, 1984; Shimamura, Janowsky, & Squire, 1990; Shimamura & Squire, 1987), as well as by in vivo neuroimaging of normal volunteers (Raz et al., 1994). Because the prefrontal association cortex is especially vulnerable to aging (Kemper, 1994; Raz, in press), mnemonic functions that rely on cognitive operations supported by this brain region may evidence differential age-related declines.

Cognitive mechanisms of age-related differences in memory for context are poorly understood (Schacter, Kihlstrom, Kaszniak & Valdiserri, 1993). For example, it is unknown whether age effects on context recall are larger than those on recognition of contextual information, as is commonly found in memory for content (Craik & McDowd, 1987). It is also unclear whether age differences in memory for context are affected by intentional encoding instructions when context becomes another target and competes with content for attention resources. Meta-analytic evidence suggests that intentional encoding instructions do not necessarily put older participants at a disadvantage on memory tasks (Verhaeghen et al., 1993). Another potential moderator of age effects is the type of contextual information to be remembered. With the wide variety of contextual details (e.g., perceptual, spatial, and temporal), it is possible that age differences are not uniform across materials and encoding modalities.

On the basis of the surveyed literature, we formulated the following hypotheses:

1. Age-related differences in memory for context would exceed those differences in memory for content.
2. Age differences in free and cued recall would exceed those differences in recognition of both content and context.
3. More intentional or effortful encoding would yield greater age differences.

In addition, without specifying the direction of the hypotheses, we explored potential mediators of primary and differential age effects on content and context memory, such as type of contextual information and task material. We categorized contextual information according to the extent to which the context could interact with, or be encoded independently from, the target stimulus (Baddeley, 1982). These categories represent different levels or domains of contextual information (M. K. Johnson, 1992; M. K. Johnson, Hashtroudi & Lindsay, 1993). Perceptual details exemplify context material that is most likely to be encoded in conjunction with content. Examples of such stimulus-related contextual features included the medium in which content information was presented, properties of an "external" human source of the content information, qualities of cognitive operations, or self as the source of content information. Some attributes, such as color, shape, size, or auditory qualities, are clearly stimulus bound. In contrast, spatiotemporal or environmental contextual features are likely to have been encoded independently from content memory material. Such contextual features include memory for spatial location, temporal order, or the learning event itself.

This is a quantitative review of studies based on memory tasks that demanded explicit recollection of previously experienced events. Thus, the scope of this review was restricted to direct tests of memory, a fact whose importance is underscored by a recent finding of greatly reduced age differences in indirect tests of context memory (Light et al., 1992). The term *context* as used in this review is conceptually similar to the term *source* defined by M. K. Johnson et al. (1993) as a construct that

> refers to a variety of characteristics that, collectively, specify the conditions under which a memory is acquired (e.g., the spatial, temporal, and social context of the event; the media and modalities through which it was perceived) (p. 3).

Although M. K. Johnson et al. (1993) state that this definition of source makes it somewhat more inclusive than the term context, they do not clarify the distinction. For the purpose of this review, the term *context* denotes all conditions and circumstances under which memory for an item was acquired, whereas the term *source* is restricted to judgments about the origin of content information.

Method

Studies

Selection of studies. We used two procedures to identify studies for this quantitative review. First, we conducted a computerized search using the PsycLit database for the last 2 decades (1974 to 1994). Key terms used to locate potential studies included memory (delimited by adult human population), source, source monitoring, reality monitoring, context, contextual, spatial, temporal, recall, recognition, incidental, and intentional. We examined the abstracts prior to study selection to eliminate studies that clearly did not meet the inclusion criteria. Second, a volume-by-volume search of potentially relevant journals was conducted to identify studies that may have appeared earlier than 1974 or were overlooked in the initial search of the PsycLit database. This included an issue-by-issue examination of journals published this year, up to and including all those published by July 1994. These journals included *Developmental Psychology, Educational Gerontology, International Journal of Aging and Human Development, Journal of Experimental Psychology: Human Learning and Memory, Journal of Experimental Psychology: Learning, Memory, and Cognition, Journal of Gerontology, Journal of Memory and Language (1985–1994), Memory and Cognition,* and *Psychology and Aging.* Third, we inspected the citations of 13 articles chosen as prototypic investigations of various aspects of content or context memory, as listed in the Social Sciences Citation Index (1981–1993). These articles were G. Cohen and Faulkner (1989); Guttentag and Hunt (1988); Hashtroudi et al. (1989); Kausler, Lichty, and Davis (1985); Kausler and Puckett (1980); Lehman and Mellinger (1984); Light and Zelinski (1983); McIntyre and Craik (1987); Mitchell et al. (1986); Park et al. (1982); Park, Puglisi, and Sovacool (1983); Perlmutter, Metzger, Nezworski, and Miller (1981); Pezdek (1983); Puglisi, Park, Smith, and Hill (1985); Rabinowitz (1989); and Schacter et al. (1984, 1991). Fourth, we reexamined the bibliographies of the major relevant reviews (Craik & Jennings, 1992; M. K. Johnson et al., 1993; Light, 1991; and Moscovitch & Winocur, 1992) to determine whether these citations contained any references not yet evaluated for inclusion in this review. These search procedures yielded 85 publications that appeared potentially acceptable for inclusion in the quantitative review.

Studies were included in the meta-analysis if they contained at least one experiment that used a young adult control group (mean age 35 years or younger) and a group of older adults (mean age 65 years or older). Each experiment had to include at least one measure of content and a separate measure of context on the same sample of participants. As a rule, these measures were part of the same task (e.g., asking a participant to recall a fact and then to identify its source). However, studies were excluded if the same measure was used to infer both context and content memory (e.g., Dywan & Jacoby, 1990, who used the rate of false alarms for name recognition for both purposes). We also excluded studies if they assessed memory for content and memory for context using very different tasks or instruments (e.g., Perlmutter et al., 1981) or if they used a single task to measure either content or context, but not both. Another reason for exclusion was lack of a controlled laboratory task. One example of such an excluded study was by Evans, Brennan, Skorpanich, and Held (1984), who tested older and younger adults' everyday memory for the spatial location and names of buildings in the city in which they resided. Studies were also discarded if the delay between presentation and testing was designed to investigate primary or short-term memory (e.g., Lorsbach, 1990). A summary of the reasons for exclusion of the studies considered for this meta-analysis is presented in Appendix B, and a complete listing of excluded studies is available from the corresponding author on request. The combined searches yielded 46 studies (see Appendix A for a complete list), contained in 34 different publications, by 21 experimenters or laboratories. Studies were considered to have come from the same laboratory if either the first or second author's name reappeared as a major author in the references and if the design was similar to previous studies by those authors.

Coding. We coded variables relevant to the hypotheses of this study, as well as other descriptive variables such as sample size, education level, and age. In addition, group means on the most frequently used cognitive measure—tests of vocabulary—were extracted from the articles and provided a useful descriptor of the studied population. A summary of demographic characteristics of the samples across studies and age differences in vocabulary scores is presented in Table 1.

As evident from Table 1, in comparison with their young counterparts, on the average, older participants had an extra year of formal schooling. They also had significantly better verbal skills. The mean ages of the groups reflect that in virtually all reviewed studies an extreme group design was used. Thus, the group differences were somewhat inflated, and a reader interested in gauging the true magnitude of age effects is advised to adjust the reported average effects downward.

The stimulus material variable referred to the subject matter of content or context memory tasks. A variety of verbal, pictorial stimuli, as well as actions and activities were used. These are displayed with examples of each type in Table 2.

Retrieval effort was categorized in two levels according to the amount of environmental support or cues provided to facilitate successful retrieval. Recognition tasks (such as distinguishing between old and new items) were assigned a label of *low effort,* whereas cued and free recall were considered *high effort* tasks. Whereas free recall, cued recall, and recognition of the content are more or less clearly defined, there may be, strictly speaking, no parallel comparison in the realm of context memory. One could argue that when the participant makes judgments about context there is virtually always some "support" or cuing in that the item itself is virtually always reintroduced to assess memory for context. Perhaps an example of a task in which memory for context approaches free recall of facts would be if participants were required to draw an item in its spatial position. Despite this lack of complete parallelism in levels of effort, there seemed to be a continuum of the amount of retrieval effort required in context memory. Those studies that required simple recognition of the context by distinguishing between old and new or correct and incorrect contextual features were classified as low retrieval effort. Studies in which participants made judgments that were based on less information than a complete re-presentation of the context were classified as medium to high retrieval effort, and these were combined for the purpose of the analysis. Thus, retrieval effort for context measures actually approximates a recognition versus cued recall dichotomy.

Table 1
Participant Characteristics in the Sample of Studies Under Review

Variable and group	*M*	*SD*
Age		
Young	21.35	2.88
Older	69.65	2.05
Education		
Young	13.99	0.88
Older	15.06	1.57
Vocabulary[a]	−0.95	0.68

[a] To provide a common metric, vocabulary is expressed as an effect size: g = (raw $\text{score}_{\text{young}}$ − raw $\text{score}_{\text{old}}$)/pooled standard $\text{deviation}_{\text{young \& old}}$.

Encoding effort was coded into two levels: *low* (incidental) and *high* (intentional). This distinction was based on reported task instructions. When the authors explicitly stated or implied that participants were not informed about the need to retain memory for content or context or when participants were led to believe that the task was not a memory task, such a task was considered to demand low encoding effort. If the experimenters explicitly informed participants that they would complete a memory test, the task was considered to require high encoding effort. Additionally, if the authors did not clearly state in their methods description, but implied that the study of certain information was the focus of participant attention, high encoding effort was assumed. Examples for this and other categories of dimensions examined in the meta-analysis are presented in Table 2.

Procedure

Effect sizes. All effect sizes were obtained using DSTAT software for meta-analysis (B. T. Johnson, 1990). In DSTAT, the effect sizes are calculated as unbiased estimates (d, see Equation 1, Appendix C), corrected for overestimation of the effect size in small samples (Hedges & Olkin, 1985). Accurate calculation of d depends on availability of key information, including the number of participants, group performance means, and their accompanying standard deviations. If these data were not reported, we computed d from F statistics with one degree of freedom and t statistics reported in the studies. In one study (G. Cohen & Faulkner, 1989), the age differences in content memory were reported as nonsignificant without providing descriptive or inferential statistics. For this study, we used a conservative estimate of $d = 0$ in the analyses. Two other studies (Puglisi et al., 1985, Experiments 1 & 2) reported nearly equivalent cell means and nonsignificant differences in statistical tests. These effect sizes were also conservatively estimated to be zero; however, they were averaged with recall measures for the main analysis. In this and subsequent analyses, these studies also did not appear as outliers. The assumptions that guided us in estimating d from secondary information are noted in Appendix A.

To determine whether the effect sizes of the sample originated from the same population, we evaluated homogeneity of individual effect sizes within each group. These analyses are based on Hedges' (1984) general equation for H_T or Q_T (Equation 3, Appendix C), a statistic that approximates a 2 distribution with (k − 1) degrees of freedom, where k is the number of cases. If the resultant value of Q_T is less than the critical 2 value at the .05 level, effect sizes are presumed homogeneous. If the test of homogeneity fails, one should break down the effect sizes into homogeneous subsets before further analysis (Hedges & Olkin, 1985). For that purpose, within-group homogeneity Q_W is calculated for each of the groups along the dimension believed to be the most likely to account for heterogeneity. Calculation of Q_W is identical to Q_T except that it is within a specific grouping of effect sizes, with $k - p$ degrees of freedom, according p subgroups and k cases within the entire group.

Table 2
Categories of Variables Coded in Each Study and Examples of Each

Category	Example
Memory type	
Content	Word recognition
Context	Source identification
Material of memory for content	
Verbal	Visually displayed words or trivia statements
Objects and pictures	Three-dimensional objects or line drawings
Actions and activities	Hand motions or series of paper-and-pencil tests
Material of memory context	
Perceptual features of the stimulus item	Upper- or lower-case text, color, or auditory qualities
Modality information	Stimulus encoded via auditory or visual modalities
Spatial features	Object location in a matrix
Event	The experimental session or personal experiences
Person	Experimenter A or B as the specific source
Self	Imagining an activity or saying a word
Temporal	Time of day or sequence of an item among other items
Self–other (reality monitoring: a combination of person and self)	Items are heard or self-generated
Retrieval effort	
Low (extensive cuing at retrieval)	Identifying item or contextual features as "old" or "new"
High (limited or no specific cues at retrieval)	Cued or free recall of an item, various source, or context judgments
Encoding effort	
Low (incidental: No explicit instructions are given to attend to and encode specific information.)	Participants believe they are performing a task of attention.
High (intentional: Explicit instructions are given or implied to specifically attend to and encode information.)	Participants are told prior to stimulus presentation that they will be tested on their memory for an item and its location.

The sum of the individual within-group homogeneity values yields the total within-group value. One can use the total within-group homogeneity to calculate a between-group homogeneity statistic (Q_B) similar to the F value yielded by conventional analysis of variance (Hedges & Olkin, 1985). Similar to the F value, a statistically significant Q_B value indicates that there is a reliable difference (heterogeneity) between the groups. If the homogeneity test Q_B was performed on more than two groups, one can perform additional contrast tests to determine which groups are reliably different in magnitude of effect sizes (Hedges & Olkin, 1985).

Within each comparison group, some studies yielded more than one effect size. In such cases, effect sizes were averaged within studies, so that each study yielded no more than one effect size for the variable of interest. Thus, 46 acceptable studies were used in calculating weighted average effect sizes ($d.$) for each comparison. Because of the selectivity of certain comparisons, not all studies were used in each analysis. On the other hand, some studies contained more than one condition or experimental manipulation, thus yielding more than the total of 46 effect sizes for some of the analyses. To maintain independence of studies in these analyses, we randomly assigned studies to only one condition each.

Results

Because context and content memory measures derived from the same study are not independent, we could not conduct effect heterogeneity analysis. To test the Hypothesis 1, we compared the 95% confidence intervals (CI95%) for the respective effect sizes instead. This comparison yielded mean effects of $d. = .72$ (CI95% = .630 to .807) for content and $d. = .90$ (CI95% = .814 to .991) for context measures. We inspected the distribution of the effects for statistical outliers. These were removed in a hierarchical stepwise manner, according to their relative weight to the within-grouping (Q_W) heterogeneity, until a statistically homogenous grouping of effect sizes was obtained (Hedges & Olkin, 1985). After removal of one outlying value for the context memory effects (Light & Zelinski, 1983) and nine outliers for content memory (Guttentag & Hunt, 1988; Hashtroudi, Johnson, Vnek, & Ferguson, 1994; Lehman & Mellinger, 1984, Experiments 1 & 2; Light & Zelinski, 1983; Mäntylä & Bäckman, 1992, Experiment 3; McIntyre & Craik, 1987, Experiment 2; Moore, Richards, & Hood, 1984; Park & Puglisi, 1985), we observed an even greater difference between the examined memory domains: $d. = .58$ (CI95% = .480 to .670) for content and $d. = .87$ (CI95% = .780 to .960) for context memory measures. Neither CI95% contained zero, meaning that significant age-related differences were observed in both mnemonic domains. The lack of overlap in CI95% indicates that, indeed, age-related differences in memory for context are reliably greater than those in content memory. According to J. Cohen's (1988) criteria, the effect for context memory can be labeled large, whereas the effect for content memory is moderate. The magnitude of the effect for content memory means that a median young participant is expected to perform at the level of the upper quartile of the older participants. The discrepancy is significantly greater for context memory: A median young participant would outperform almost 82% of the older participants.

To examine the mediators of these differences, the effects for content and context memory were grouped according to the type of stimuli and the perceived retrieval and encoding effort involved in a given task.

The results of these analyses presented in Tables 3–5 revealed several significant mediating variables.

Tables 3–5 summarize the data analyses before removal of statistical outliers. As predicted in Hypothesis 2, more effortful modes of retrieval (free and cued recall) elicited greater age differences than recognition. Notably, the average effects for the two levels of retrieval effort are very close to those found by La Voie and Light (1994) in a sample of studies that did not overlap with ours. We found effects of 1.01 and 0.57 for recall and recognition, respectively, whereas La Voie and Light reported 0.97 for recall and 0.50 for recognition. Hypothesis 3 was not sustained in the total sample (see Table 3). It was, however, confirmed after the removal of three outliers from the low encoding effort condition (Guttentag & Hunt, 1988; Lehman & Mellinger, 1984, Experiment 1; Moore et al., 1984) and five outliers from the high encoding effort condition (Lehman & Mellinger, 1984, Experiment 2; Light & Zelinski, 1983; Mäntylä & Bäckman, 1992, Experiment 3; McIntyre & Craik, 1987, Experiment 2; Park & Puglisi, 1985). Specifically, we observed a small but reliable effect of intentionality of encoding on the magnitude of age differences in content memory (Q_B = 4.35, $p < .05$). Although in both conditions removal of the outliers resulted in reduction of the effect sizes, studies with intentional encoding produced larger effects than those in which incidental encoding procedures were used: $d.$ = .62 versus $d.$ = .41. On the other hand, apparent age differences in content memory for various materials did not remain after outliers were removed (Q_B = 1.91, p = .39; Hashtroudi et al., 1994; Lehman & Mellinger, 1984, Experiments 1 & 2; Light & Zelinski, 1983; Mäntylä & Bäckman, 1992, Experiment 3; McIntyre & Craik, 1987, Experiment 2; Moore et al., 1984; Park & Puglisi, 1985).

To examine the interaction between encoding and retrieval of content, we divided the studies into four groups: low encoding effort–low retrieval effort (low–low condition), high encoding effort–high retrieval effort, and the combinations of the two. We contrasted the average weighted effect size of the low-low condition ($d.$ = .37) against the weighted mean of the other three conditions ($d.$ = .86, Q_W = 73.68) and found the difference statistically significant (Q_B = 22.47, $p < .01$). However, after removal of the outliers, we found no significant effect of intentionality of encoding under both levels of retrieval effort (see Table 4). Nevertheless, the effect of larger effect sizes for recall than retrieval remained.

The effects for age-related differences in context memory were homogeneous, after the removal of one outlier (Light & Zelinski, 1983; Q_W = 46.19, p = .78). It appears that some powerful factors associated with age affect context memory in a uniform homogenizing manner. Thus, we could have stopped analysis at this point, declaring that a single model fits context effect sizes adequately. However, for the sake of comparison with content memory, we conducted a similar series of homogeneity testing on effect sizes for context memory. In a notable contrast to content memory, the amount of effort required at retrieval made no impact on age-related differences in context memory, even after the outlier was removed (Q_B = .31, p = .57). Encoding effort also had no influence on age-related differences in context memory after elimination of three statistical outliers within the condition of intentionally encoded context (Park et al., 1982; Park & Puglisi, 1985, Experiment 1; Schwartz, Hashtroudi, Herting, & Deutsch, 1992; Q_B = .48, p = .49).

We were able to identify one source of heterogeneity in effect sizes after categorizing the effects according to types of context in which target information was acquired. The analysis presented in Table 5 suggests that memory for more general aspects of the learning context produced larger age-related effects than memory for specific stimulus-bound information such as a target's color or size. Older participants may show less impairment in recollection of contextual information that is encoded interactively with content; however, their ability to remember specific context features that are less intrinsically associated with the content is impaired.

To determine whether age differences in context and content memory are closely related, we computed the correlation between the effects sizes for these two measures. The results do not suggest close association between age-related declines in the examined memory domains (see Figure 1). The modest correlation of r = .31 ($p < .05$) dropped to a nonsignificant r = .22 after removal of one outlier (Lehman & Mellinger, 1984, Experiment 2).

Table 3
Tests of Effect Size Homogeneity for Content Memory Tasks

Category	n	$d.$	Q_W	Total
Retrieval effort				
Low (recognition)	27	0.57	111.50*	Q_T = 210.44
High (recall)	19	1.01	78.25*	Q_B = 20.69*
Encoding effort				
Low (Incidental)	18	0.65	83.47*	Q_T = 208.18
High (Intentional)	28	0.76	123.28*	Q_B = 1.43
Material				
Verbal	29	0.57	87.42*	Q_T = 220.06
Objects and pictures	11	1.07	89.76*	Q_B = 22.51*
Actions	6	0.74	20.38*	

Note. Q_W is a within-group homogeneity statistic; Q_B is a between-group homogeneity statistic; Q_T is a total homogeneity statistic.
* $p < .05$, indicating significant lack of homogeneity of the effect size.

Discussion

At first glance, it appears that, as predicted, age-related differences in context memory are reliably greater than those in memory for content. The picture is, however, complicated by two additional findings suggesting that the impact of aging on context memory is limited by the extent it may affect cognitive functions requiring effortful operations. First, when we examined tasks demanding a high degree of environmental and contextual support, age differences in memory for content reached the magnitude observed for context memory. Older people appear as deficient in recall of target information as they are in recall or recognition of contextual details associated with its acquisition. Second, differential age-related deficits in context memory may be restricted to spatiotemporal, extra-stimulus context; the magnitude of age-related differences in memory for stimulus-bound contextual details is comparable with that observed in memory for facts. Thus, older adults appear excessively affected by factors that impoverish contextual support of content

Table 4
Effect Size Analysis for Content Memory Tasks by Retrieval and Encoding Effort

	Low effort (recognition)			High effort (recall)			Total	
Category	*n*	*d.*	Q_W	*n*	*d.*	Q_W	Q_T	Q_B
Incidental encoding (low)	13	0.37	19.46	5	1.72	15.42	83.47	48.59
Intentional encoding (high)	14	0.73	81.68	14	82	48.12	130.41	0.62
Total								
Q_T		111.24			85.28			
Q_B		10.11*			21.74*			

Note. Q_W is a within-group homogeneity statistic; Q_B is a between-group homogeneity statistic; Q_T is a total homogeneity statistic. For all Q_W, the effect sizes are homogeneous within groups.
* $p < .05$, indicating significant between group heterogeneity of effect size.

memory and by task conditions that require access to contextual information only loosely associated with the stimulus. When contextual information is closely related to the target, age differences in memory for context are reduced almost by half. Given this evidence, it is tempting to conclude that there is nothing exceptional about age-related differences in context memory and that the mechanisms that underlie them are similar to those responsible for age-related declines in other memory functions. However, several findings in this meta-analysis contradict that view. For example, age-associated differences in memory for context are insensitive to the amount of effort required at retrieval: Recognition and recall yield comparable effects. Age effects on context and content memory do not correlate highly across the studies. Thus, these mnemonic functions may be fairly independent, although within studies a moderate degree of association between the two has been reported (e.g., Spencer & Raz, 1994).

How can we explain the observed pattern of differential age effects on content and context memory? A Multiple Entry Modular (MEM) memory system model (M. K. Johnson, 1992; M. K. Johnson et al., 1993; M. K. Johnson & Hirst, 1991) offers a way to conceptualize the process involved in effective binding of content and context information. M. K. Johnson (1992) proposed that agenda-driven reflective processes determine whether effective binding of central aspects of memory (content) to contextual information occurs. Furthermore, information that is agenda relevant (i. e., goal driven) is most likely to get rehearsed, whereas information that is peripheral to the agenda receives more limited maintenance. The process of repeated rehearsal may be most crucial to the binding or strengthening of the connections of memory content and context (M. K. Johnson, 1992). Agendas may operate in a more or less effortful manner. Agendas may be either systematic (exhaustive and effortful goal-directed processes) or heuristic (well-learned processes, used in either a controlled or automatic manner; M. K. Johnson et al., 1993). The central executive may activate, monitor, and adjust relatively independent (modular) agendas in its operation to process information efficiently and strategically. Agendas may organize relevant information, focus attention, or direct rehearsal of important information, which are all properties of the "working-with-memory" system (Moscovitch, 1992).

At least three cognitive mechanisms may underlie age-related differences in system agendas: poor division of attention, limitation of working memory capacity, and failure of inhibitory processes. These mechanisms are distinct but not necessarily independent and may influence each other. Thus, specific patterns of cognitive performance may result from interactions among them. Encoding of numerous contextual features simultaneously with encoding of target information requires distribution of attentional resources. It also needs working memory as a buffer to couple the incoming flow of information with internal processing rate. During retrieval, working memory may play a role of temporary buffer for evaluation and verification of items. Working memory capacity becomes especially important

Table 5
Tests of Effect Size Homogeneity for Context Memory Tasks

Category	*n*	*d.*	Q_W	Total
Retrieval effort				
Low (recognition)	19	0.93	34.10*	Q_T = 66.53
High (recall)	27	0.90	32.37	Q_B = 0.10
Encoding effort				
Low (incidental)	27	0.92	24.46	Q_T = 68.57
High (intentional)	19	0.88	41.97*	Q_B = 0.14
Material				
Stimulus-related	33	0.80	29.15	Q_T = 61.29
Environmental (spatiotemporal)	13	1.17	17.84	Q_B = 14.30*

Note. Q_W is a within-group homogeneity statistic; Q_B is a between-group homogeneity statistic; Q_T is a total homogeneity statistic.
* $p < .05$, indicating significant lack of homogeneity of the effect size.

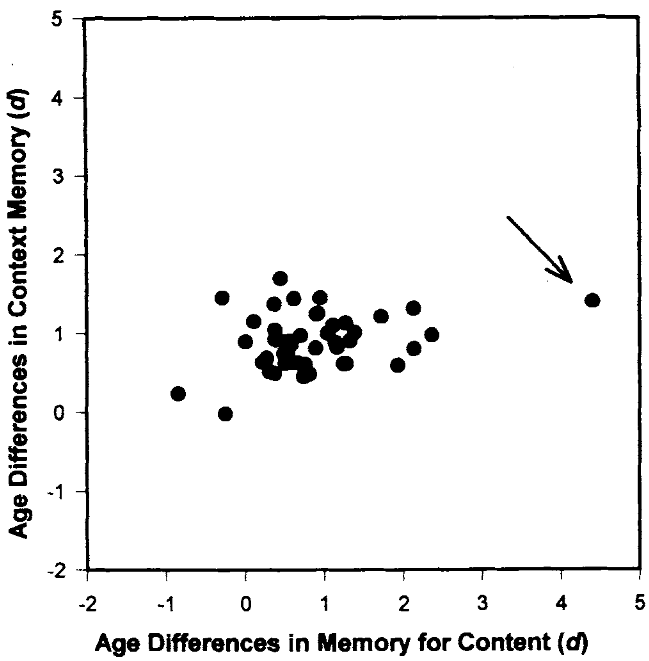

Figure 1. Distribution of age differences in content and context memory expressed as effect sizes (*d*). The outlier is indicated by an arrow.

when numerous contextual features are to be retrieved either in conjunction with the target or in their own right. Retrieval also necessitates inhibition of irrelevant competing information, and, when multiple contextual details are to be retrieved simultaneously, inhibitory control processes become even more important in maintaining optimal signal-to-noise ratio. There is no direct experimental evidence bearing on the relative importance of these three factors in memory for context; circumstantial evidence, however, abounds.

Age-related declines in ability to divide attention among two or more streams of stimuli have been clearly established (Hartley, 1992). Thus, it is possible that differential age-associated declines in context memory are caused by failure of attention deployment during stimulus encoding. It appears from the meta-analysis that instructions to intentionally encode content information resulted in larger age effects in memory for this information. However, the meta-analysis shows that, in context memory, intentional and incidental encoding yield age differences of similar magnitude. As a matter of fact, incidental encoding (during which participants pay little or no attention to the stimuli) in combination with low retrieval effort yields relatively smaller age differences in content memory.

Limitations of working memory may cause problems both in encoding and retrieval. These limitations include failure of specific working memory modules, such as articulatory loop (Baddeley, 1986), as well as impairment of central executive processes such as "working-with-memory" (Moscovitch, 1992). As in the case of divided attention, there is no direct evidence of working memory failure as a factor in differential age-related impairment of context memory. However, working memory is as clearly impaired in healthy older adults as is the ability to divide attention (Salthouse, 1992). Thus, it is possible that memory functions are affected by aging to the extent that they depend on working memory: The greater the role working memory plays in maintaining a given function, the larger the magnitude of age-related differences is in that function. In context retrieval, the role of working memory may be very prominent, especially when environmental (spatiotemporal) details are concerned. Kimberg and Farah (1993) have demonstrated through computer simulation that breakdown of working memory may account for a variety of cognitive problems, including failure of memory for context.

Spatiotemporal contextual information may appear less relevant to the target stimuli than specific perceptual features, yet it may be crucial in distinguishing episodes of learning (Tulving, 1983). Formerly, spatial and temporal characteristics of the stimuli were thought to be encoded automatically (Hasher & Zacks, 1979). However, this hypothesis has been repeatedly rejected. A series of studies has demonstrated that encoding of spatial and temporal information is sensitive to manipulations that affect effortful processing (Naveh-Benjamin, 1987, 1988, 1990). Successful recollection of spatial and temporal features may depend on how well contextual information is managed. Even if encoded properly, context may become easily disengaged from content. Thus, it may become difficult to retrieve information about other spatial locations or temporal events, or to distinguish among them. The result is a variety of errors in source monitoring (e.g., source amnesia, confabulation, "false fame," etc.; for a discussion of such errors, see M. K. Johnson et al., 1993) as well as intrusion errors in memory for content (Kliegl & Lindenberger, 1993).

According to one model, it is the ability to successfully manipulate this information that is highly related to the functioning of the frontal lobe's executive, or working-with-memory system (Moscovitch & Winocur, 1992; Schacter, 1987). Hence, the finding that age differences were larger for spatiotemporal rather than perceptual context suggests that differential decline of memory for context may indeed be related to age-associated decline of frontal executive systems. Proficiency in context retrieval is related to the integrity of the dorsolateral prefrontal cortex (Raz et al., 1994). The prefrontal cortex is also important in memory for temporal order (Petrides, 1991) and in working memory (D'Esposito et al., 1994; Swartz, Halgren, Fuster, & Blahd, 1994). Thus, one may expect enhancement of age-related deficits in context retrieval by manipulations that tax working memory. In addition, it can be predicted that proficiency on working memory tests will correlate positively with success in recall of contextual information and that this association will be stronger than the link between working memory and recall of content.

Finally, we can speculate about how failure of inhibitory processes may result in greater age-related declines in context memory in comparison with memory for content. Diminished degree of inhibitory control has been observed in normal older adults and in patients with lesions involving the prefrontal cortex (Stuss & Benson, 1984). Disinhibition may result in the introduction of irrelevant information or unnecessary cognitive operations to working memory, overloading it and creating a capacity bottleneck. Therefore, Hasher and Zacks (1988) argued, working memory deficits may stem from failure of inhibition. Compromised inhibitory processes may result in both encoding and retrieval difficulties, and, as Hasher and Zacks (1988) suggest, cooccurrence of relevant and irrelevant information creates competing response possibilities, or "noise," creating difficulties in response selection. Additionally, disinhibition leads to the deployment of non-goal-related or idiosyncratic agendas during encoding or retrieval, resulting in allocating resources to (working with) task-irrelevant information. All these factors may produce numerous errors of memory processing, and, as a result of experiences with memory errors, older adults learn to adopt less elaborate, less effortful, more stereotyped response strategies (i.e., relying on personal knowledge, environmental cues, familiarity, and other heuristics) as compensatory mechanisms (Hasher & Zacks, 1988). These compensatory strategies may be effective in situations when the demand for retrieval effort is low, as in recognition paradigms with highly distinctive items. However, when more than one type of information is to be encoded (content with context), or when information becomes less distinct, these strategies may fail, resulting in memory errors such as confabulation, source amnesia, false fame, and intrusion errors (M. K. Dywan & Jacoby, 1990; Johnson et al., 1993; Kliegl & Lindenberger, 1993).

One important caveat to accompany this review is that virtually all studies included in it share a common design feature. Memory for an item's source and context is assessed only if there is evidence of memory for the item itself. This dependence has been identified as a problem by Batchelder and Riefer (1990), who also proposed a remedy in the form of multinomial models. In some cases, the results of such modeling contradict the findings obtained with more traditional designs. Unfortunately, in none of the studies included in this meta-analysis were multinomial models applied. Thus, it is possible that future research will yield data that could challenge our conclusions.

In summary, meta-analytic integration of the findings on age-related differences in memory for content and context suggests that these memory functions respond differently to aging. Overall, the differences in memory for context are larger. The magnitude of age-related differences in content memory depends on the attention allocation at encoding and the amount of effort required at retrieval, whereas age-related differences in context memory are insensitive to these factors. The magnitude of age differences in context memory depends on the relevance of the context to the targeted content. Dependence on executive processes that are implemented in the prefrontal cortex may be a specific characteristic of context memory that sets it apart from other memory functions such as memory for content, which relies mainly on the limbic–diencephalic system (Squire, 1987). Further exploration of these relationships between cognitive operations and their neural substrates should bring new insights into the mechanisms of differential age-related declines in memory.

References

Baddeley, A. D. (1982). Domains of recollection. *Psychological Review, 89,* 708–729.

Baddeley, A. D. (1986). *Working memory.* Oxford, England: Clarendon Press.

Batchelder, W. H., & Riefer, D. M. (1990). Multinomial processing models of source monitoring. *Psychological Review, 97,* 548–564.

Cohen, G., & Faulkner, D. (1989). Age differences in source forgetting: Effects on reality monitoring and on eyewitness testimony. *Psychology and Aging, 4,* 10–17.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences.* Hillsdale, NJ: Erlbaum.

Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In F. I. M. Craik and T. A. Salthouse (Eds.), *Handbook of aging and cognition* (pp. 51–110). Hillsdale, NJ: Erlbaum.

Craik, F. I. M., & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 474–479.

Craik, F. I. M., Morris, L. W., Morris, R. G., & Loewen, E. R. (1990). Relations between source amnesia and frontal lobe functioning in older adults. *Psychology and Aging, 5,* 148–151.

Denney, N. W., Dew, J. R., & Kihlstrom, J. F. (1992). An adult developmental study of the encoding of spatial location. *Experimental Aging Research, 18,* 25–32.

Denney, N. W., Miller, B. V., Dew, J. R., & Levav, A. L. (1991). An adult developmental study of contextual memory. *Journal of Gerontology: Psychological Sciences, 46,* P44–P50.

D'Esposito, M., Detre, J. A., Alsop, D. C, Listerud, J., Atlas, S. W., & Grossman, M. (1994). Activation of dorsolateral prefrontal cortex during a dual-task working memory paradigm using functional MRI. *Society for Neuroscience Abstracts, 20,* 6.

Dywan, J., & Jacoby, L. L. (1990). Effects of aging on source monitoring: Differences in susceptibility to false fame. *Psychology and Aging, 3,* 379–387.

Evans, G. W., Brennan, P. L., Skorpanich, M. A., & Held, D. (1984). Cognitive mapping and elderly adults: Verbal and location memory for urban landmarks. *Journal of Gerontology, 39,* 452–457.

Ferguson, S. A., Hashtroudi, S., & Johnson, M. K. (1992). Age differences in using source-relevant cues. *Psychology and Aging, 7,* 443–452.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 23,* 553–568.

Gregory, M. E., Mergler, N. L., Durso, F. T., & Zandi, T. (1988). Cognitive reality monitoring in adulthood. *Educational Gerontology, 14,* 1–13.

Guttentag, R. E., & Hunt, R. R. (1988). Adult age differences in memory for imagined and performed actions. *Journal of Gerontology: Psychological Sciences, 43,* P107–P108.

Hartley, A. A. (1992). Attention. In F. I. M. Craik & T. A. Salthouse (Eds.), *Handbook of aging and cognition* (pp. 3–49). Hillsdale, NJ: Erlbaum.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356–388.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of Learning and Motivation, 22,* 193–225.

Hashtroudi, S., Johnson, M. K., & Chrosniak, L. D. (1989). Aging and source monitoring. *Psychology and Aging, 4,* 106–112.

Hashtroudi, S., Johnson, M. K., Vnek, N., & Ferguson, S. A. (1994). Aging and the effects of affective and factual focus on source monitoring and recall. *Psychology and Aging, 9,* 160–170.

Hedges, L. V. (1984). Advances in statistical methods for meta-analysis. In W. H. Yeaton & P. M. Wortman (Eds.), *Issues in data synthesis* (pp. 25–42). San Francisco: Jossey-Bass.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis.* San Diego, CA: Academic Press.

Janowsky, J., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia, 27,* 1043–1056.

Johnson, B. T. (1990). *DSTAT.* Hillsdale, NJ: Erlbaum.

Johnson, M. K. (1992). MEM: Mechanisms of recollection. *Journal of Cognitive Neuroscience, 4,* 268–280.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin, 114,* 3–28.

Johnson, M. K., & Hirst, W. (1991). Processing subsystems of memory. In R. G. Lister & H. J. Weingartner (Eds.), *Perspectives on cognitive neuroscience* (pp. 197–217). New York: Oxford University Press.

Kausler, D. H., Lichty, W., & Davis, R. T. (1985). Temporal memory for performed activities: Intentionality and adult age differences. *Developmental Psychology, 21,* 1132–1138.

Kausler, D. H., Lichty, W., & Freund, J. S. (1985). Adult age differences in recognition memory and frequency judgments for planned versus performed activities. *Developmental Psychology, 21,* 647–654.

Kausler, D. H., & Phillips, P. L. (1989). Instructional variation and adult age differences in activity memory. *Experimental Aging Research, 14,* 195–199.

Kausler, D. H., & Puckett, J. M. (1980). Adult age differences in recognition memory for a nonsemantic attribute. *Experimental Aging Research, 6,* 349–355.

Kausler, D. H., & Puckett, J. M. (1981a). Adult age differences in memory for modality attributes. *Experimental Aging Research, 7,* 117–125.

Kausler, D. H., & Puckett, J. M. (1981b). Adult age differences in memory for sex of voice. *Journal of Gerontology, 36,* 44–50.

Kausler, D. H., & Wiley, J. G. (1990). Temporal memory and content memory for actions: Adult age differences in acquisition and retention. *Experimental Aging Research, 16,* 147–150.

Kemper, T. L. (1994). Neuroanatomical and neuropathological changes during aging and in dementia. In M. L. Albert & E. J. E. Knoepfel (Eds.), *Clinical neurology of aging* (2nd ed., pp. 3–67). New York: Oxford University Press.

Kimberg, D. Y., & Farah, M. J. (1993). A unified account of cognitive impairments following frontal lobe damage: The role of working memory in complex, organized behavior. *Journal of Experimental Psychology: General, 122,* 411–428.

Kliegl, R., & Lindenberger, U. (1993). Modeling intrusions and correct recall in episodic memory: Adult age differences in encoding list context. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 617–637.

La Voie, D., & Light, L. L. (1994). Adult age differences in repetition priming: A meta-analysis. *Psychology and Aging, 9,* 539–553.

Lehman, E. B., Bovasso, M., Grout, L. A., & Happ, L. K. (1991). Orientation task effects on memory for presentation modality in children, young adults, and older adults. *The Journal of General Psychology, 119,* 15–27.

Lehman, E. B., & Mellinger, J. C. (1984). Effects of aging on memory for presentation modality. *Developmental Psychology, 20,* 1210–1217.

Lehman, E. B., & Mellinger, J. C. (1986). Forgetting rate and modality memory for young, mid-life, and older women. *Psychology and Aging, 1,* 178–179.

Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology, 42,* 333–376.

Light, L. L., La Voie, D., Valencia-Laver, D., Albertson-Owens, S. A., & Mead, G. (1992). Direct and indirect measures of memory for modality in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1284–1297.

Light, L. L., & Zelinski, E. M. (1983). Memory for spatial information in young and old adults. *Developmental Psychology, 19,* 901–906.

Lorsbach, T. C. (1990). Buildup of proactive inhibition as a function of temporal spacing and adult age. *American Journal of Psychology, 103,* 21–36.

Mäntylä, T., & Bäckman, L. (1992). Aging and memory for expected and unexpected objects in real-world settings. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1298–1309.

McAndrews, M. P., & Milner, B. (1991). The frontal cortex and memory for temporal order. *Neuropsychologia, 29,* 849–859.

McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology, 41,* 175–192.

Mellinger, J. C., Lehman, E. B., Happ, L. K., & Grout, L. A. (1990). Cognitive effort in modality retrieval by young and older adults. *Experimental Aging Research, 16,* 35–41.

Mitchell, D. B., Hunt, R. R., & Schmitt, F. A. (1986). The generation effect and reality monitoring: Evidence from dementia and normal aging. *Journal of Gerontology, 41,* 79–84.

Moore, T. E., Richards, B., & Hood, J. (1984). Aging and the coding of spatial information. *Journal of Gerontology, 39,* 210–212.

Moscovitch, M. (1992). Memory and working-with-memory: A component process model based on modules and central systems. *Journal of Cognitive Neuroscience, 4,* 257–267.

Moscovitch, M., & Winocur, G. (1992). Neuropsychology of memory and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *Handbook of aging and cognition* (pp. 315–372). Hillsdale, NJ: Erlbaum.

Naveh-Benjamin, M. (1987). Coding of spatial location information: An automatic process? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 595–605.

Naveh-Benjamin, M. (1988). Recognition memory of spatial location information: Another failure to support automaticity. *Memory and Cognition, 16,* 437–445.

Naveh-Benjamin, M. (1990). Coding of temporal order information: An automatic process? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 117–126.

Park, D. C., & Puglisi, J. T. (1985). Older adults' memory for the color of pictures and words. *Journal of Gerontology, 40,* 198–204.

Park, D. C., Puglisi, J. T., & Lutz, R. (1982). Spatial memory in older adults: Effects of intentionality. *Journal of Gerontology, 37,* 330–335.

Park, D. C., Puglisi, J. T., & Sovacool, M. (1983). Memory for pictures, words, and spatial location in older adults: Evidence for pictorial superiority. *Journal of Gerontology, 38,* 582–588.

Perlmutter, M., Metzger, R., Nezworski, T., & Miller, K. (1981). Spatial and temporal memory in 20 and 60 year olds. *Journal of Gerontology, 36,* 59–65.

Petrides, M. (1991). Functional specialization within the dorsolateral frontal cortex for serial order memory. *Proceedings of Royal Society of London, B, 246,* 299–306.

Pezdek, K. (1983). Memory for items and their spatial locations by young and elderly adults. *Developmental Psychology, 19,* 895–900.

Puglisi, J. T., Park, D. C., Smith, A. D., & Hill, G. W. (1985). Memory for two types of spatial location: Effects of instructions, age, and format. *American Journal of Psychology, 98,* 101–118.

Rabinowitz, J. C. (1989). Judgments of origin and generation effects: Comparisons between young and elderly adults. *Psychology and Aging, 4,* 259–268.

Raz, N. (in press). Neuroanatomy of the aging brain observed in vivo: A review of structural MRI findings. In E. D. Bigler (Ed.), *Handbook of human brain function: Neuroimaging* (Vol. 3). New York: Plenum Press.

Raz, N., Spencer, W. D., Briggs, S. D., Thornton, A. E., Loken, W. J., & Acker, J. D. (1994, March). *Neuroanatomic substrates of memory for facts and context: Preliminary evidence of dissociation in the aging brain.* Paper presented at the first meeting of the Cognitive Neuroscience Society, San Francisco.

Salthouse, T. A. (1992). *Mechanisms of age-cognition relations in Adulthood.* Hillsdale, NJ: Erlbaum.

Schacter, D. L. (1987). Memory, amnesia, and frontal lobe dysfunction. *Psychobiology, 15,* 21–36.

Schacter, D. L., Harbluk, J. L., & McLachlan, D. R. (1984). Retrieval without recollection: An experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior, 23,* 593–611.
Schacter, D. L., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1991). The relation between source memory and aging. *Psychology and Aging, 6,* 559–568.
Schacter, D. L., Kihlstrom, J. F., Kaszniak, A. W., & Valdiserri, M. (1993). Preserved and impaired memory functions in elderly adults. In J. Cerella, J. Rybash, W. Hoyer, & M. L. Common (Eds.), *Adult information processing: Limits on loss* (pp. 327–350). New York: Academic Press.
Schacter, D. L., Osowiecki, D., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1994). Source memory: Extending the boundaries of age-related differences. *Psychology and Aging, 9,* 81–89.
Schwartz, B. L., Hashtroudi, S., Herting, R. L., & Deutsch, S. I. (1992). The effects of milacemide on item and source memory. *Clinical Neuropharmacology, 15,* 114–119.
Shimamura, A. P., Janowsky, J. S., & Squire, L. R. (1990). Memory for the temporal order of events in patients with frontal lobe lesions and amnesic patients. *Neuropsychologia, 28,* 803–813.
Shimamura, A. P., & Squire, L. R. (1987). A neuropsychological study of fact memory and source amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 464–473.
Smith, S. M., Glenberg, A., & Bjork, R. A. (1978). Environmental context and human memory. *Memory and Cognition, 6,* 342–353.
Spencer, W. D., & Raz, N. (1994). Memory for facts, source, and context: Can frontal lobe dysfunction explain age-related differences? *Psychology and Aging, 9,* 149–159.
Squire, L. R. (1987). *Memory and brain.* New York: Oxford University Press.
Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. *Psychological Bulletin, 95,* 3–28.
Swartz, B. E., Halgren, E., Fuster, J., & Blahd, W. H. (1994) Visual working memory in humans. *Society for Neuroscience Abstracts, 20,* 358.
Tulving, E. (1983). *Elements of episodic memory.* New York: Oxford University Press.
Verhaeghen, P., Marcoen, A., & Goossens, L. (1993). Facts and fiction about memory aging: A quantitative integration of research findings. *Journal of Gerontology: Psychological Sciences, 48,* P157–P171.
Zelinski, E. M., & Light, L. L. (1988). Young and older adults' use of context in spatial memory. *Psychology and Aging, 3,* 99–101.

Appendix A

Studies Included in Quantitative Review

Study	*N* Young	*N* Old	Tasks used for memory of content (CN) and context (CX)	How effect size was calculated	*d*[a] CN	*d*[a] CX
Cohen & Faulkner (1989)	24	18 18	CN: action recognition CX: reality monitoring	Used *Ms*, *SDs*	0.00	0.89
Denney, Dew, & Kihlstrom (1992)	54	54	CN: word recognition CX: spatial location	Used *Ms*, *SDs*	0.38	1.04
Denney, Miller, Dew, & Levav (1991)	54	54	CN: word, background recognition CX: background, word recognition (incidental "context")	Used *Ms*, *SDs*	0.49	0.74
Ferguson, Hashtroudi, & Johnson (1992, Experiment 1)	40	40	CN: word recognition CX: identification of presenter	Used *Ms*, *SDs*	0.27	0.68
Ferguson et al. (1992, Experiment 2)	32	32	CN: word recognition CX: identification of presenter	Used *Ms*, *SDs*	0.51	0.89
Ferguson et al. (1992, Experiment 3)	32	32	CN: word recognition CX: identification of presenter	Used *Ms*, *SDs*	0.89	0.81
Gregory, Mergler, Durso, & Zandi (1988)	20	20	CN: word recognition CX: reality monitoring	CN: Used *Ms*, *SDs* CX: computed directly from *F*	0.37	0.49
Guttentag & Hunt (1988)	16	16	CN: free recall of actions CX: reality monitoring	CN: calculated directly from *F* CX: calculated directly from *t*	2.36	0.97
Hashtroudi, Johnson, & Chrosniak (1989)	64	64	CN: word recognition CX: source monitoring	Used *Ms*, *SDs*	0.57	0.90
Hashtroudi, Johnson, Vnek, & Ferguson (1994)	24	24	CN: recognition of statements CX: source monitoring	Used *Ms*, *SDs*	−0.29	1.45
Kausler, Lichty, & Davis (1985)	36	36	CN: free recall of actions CX: temporal judgment, serial order	Used *Ms*, *SDs*	0.81	0.48
Kausler, Lichty, & Freund (1985)	24	24	CN: activity recognition CX: reality monitoring	Used *Ms*, *SDs*	0.74	0.45
Kausler & Phillips (1989)	48	48	CN: free recall of activities CX: temporal order	Used *Ms*, *SDs*	0.90	1.24
Kausler & Puckett (1980)	24	24	CN: word recognition CX: case format recognition	Used *Ms*, *SDs*	0.54	0.75
Kausler & Puckett (1981a)	24 48	24 48	CN: word recognition CX: identification of presenter sex, case format recognition	Used *Ms*, *SDs*	0.60	0.62

Appendix A (*continued*)

Study	N Young	N Old	Tasks used for memory of content (CN) and context (CX)	How effect size was calculated	d^a CN	d^a CX
Kausler & Puckett (1981b)	20	20	CN: cued recall words CX: identification of presenter sex	Used *Ms*, *SDs*	1.24	0.61
Kausler & Wiley (1990)	32	32	CN: action recognition CX: temporal order judgment	Used *Ms*, *SDs*	1.04	1.00
Lehman, Bovasso, Grout, & Happ (1991)	24	24	CN: free recall of words CX: modality identification	*Ms* given, estimate of pooled *SD* obtained from F^b	1.32	0.90
Lehman & Mellinger (1984, Experiment 1)	32	32	CN: recall of words CX: modality identification	*Ms* given, estimate of pooled *SD* obtained from F^b	2.13	0.80
Lehman & Mellinger (1984, Experiment 2)	16	16	CN: recall of words CX: modality identification	*Ms* given, estimate of pooled *SD* obtained from F^b	4.40	0.40
Lehman & Mellinger (1986)	16	16	CN: word recognition CX: modality identification	*Ms* given, estimate of pooled *SD* obtained from F^b	0.95	1.45
Light, La Voie, Valencia-Laver, Albertson-Owens, & Mead (1992, Experiment 1)	32	32	CN: word recognition CX: modality identification	Used *Ms*, *SDs*	0.11	1.15
Light et al. (1992, Experiment 2)	32	32	CN: word recognition CX: modality identification	Used *Ms*, *SDs*	0.22	0.63
Light & Zelinski (1983)	46	46	CN: picture recognition CX: identification of spatial location	*Ms* given, estimate of pooled *SD* obtained from F^b	1.11	1.10
Mäntylä & Bäckman (1992, Experiment 1)	16	16	CN: object recognition CX: identification of perceptual alterations	Calculated directly from *F*	0.51	0.62
Mäntylä & Bäckman (1992, Experiment 2)	12	12	CN: free recall, recognition of objects CX: identification of spatial location, perceptual alterations	Used *Ms*, *SD;* also calculated directly from *F*	1.28	0.61
Mäntylä & Bäckman (1992, Experiment 3)	16	16	CN: object recognition CX: identification of perceptual alterations	*Ms* given, estimate of pooled *SD* obtained from F^b	−0.85	0.24
McIntyre & Craik (1987, Experiment 1)	30	30	CN: cued recall of facts CX: modality identification, general event identification	*Ms* given, estimate of pooled *SD* obtained from F^b	0.70	0.97
McIntyre & Craik (1987, Experiment 2)	24	24	CN: cued recall of facts CX: modality identification, general event identification	*Ms* given, estimate of pooled *SD* obtained from F^b	1.93	0.59
Mellinger, Lehman, Happ, & Grout (1990)	16	16	CN: free recall of words CX: modality identification	CN and CX calculated directly from *F*	0.55	0.89
Mitchell, Hunt, & Schmitt (1986)	12	12	CN: word cued recall CX: internal source monitoring	Computed directly from *t*; used means, standard deviations	1.14	0.88
Moore, Richards, & Hood (1984)	56	25	CN: free recall of shapes CX: placing shapes in spatial location	*Ms* given, estimate of pooled *SD* obtained from F^b	2.13	1.31
Park & Puglisi (1985)	47	45	CN: word, picture recognition CX: color identification	*Ms* given, estimate of pooled *SD* obtained from F^b	1.72	1.21
Park, Puglisi, & Lutz (1982)	30	30	CN: picture recognition CX: identification of spatial location	*Ms* given, estimate of pooled *SD* obtained from F^b	0.37	1.37
Park, Puglisi, & Sovacool (1983)	46	49	CN: picture, word recognition CX: identification of spatial location	Used *Ms*, *SDs*	0.31	0.91
Pezdek (1983)	56	56	CN: free recall of objects, words CX: placing object or word in spatial location	*Ms* given, estimate of pooled *SD* obtained from F^b	1.38	1.01

(*Appendixes continue on next page*)

Appendix A (*continued*)

Study	*N*		Tasks used for memory of content (CN) and context (CX)	How effect size was calculated	d^a	
	Young	Old			CN	CX
Puglisi, Park, Smith, & Hill (1985, Experiment 1)	28	24	CN: free recall, recognition of objects CX: spatial location	Cell means calculated from given marginal *M*s; estimate of pooled *SD* obtained from F^a; reported *n*s and means, assumed $d = 0$	0.45	1.70
Puglisi et al. (1985, Experiment 2)	48	48	CN: free recall, recognition of words and objects CX: spatial location of words or objects	Cell means calculated from given marginal *M*s; estimate of pooled *SD* obtained from F^a; reported *n*s and means, assumed $d = 0$	0.58	0.86
Rabinowitz (1989, Experiment 1)	20	20	CN: word recognition CX: reality monitoring	Used *M*s, *SD*s	1.16	0.82
Rabinowitz (1989, Experiment 2)	20	20	CN: free recall, recognition of words CX: reality monitoring	Used *M*s, *SD*s	0.76	0.60
Schacter, Kaszniak, Kihlstrom, & Valdiserri (1991)	40	40	CN: cued recall of facts CX: identification of presenter, general event	Used *M*s, *SD*s	0.31	0.51
Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri (1994, Experiment 1)	32	32	CN: cued recall of facts CX: identification of presenter	Used *M*s, *SD*s	0.62	1.44
Schacter et al. (1994, Experiment 2)	16	16	CN: cued recall of facts CX: identification of presenter	Used *M*s, *SD*s	1.27	1.13
Schwartz, Hashtroudi, Herting, & Deutsch (1992)	16	16	CN: word recognition CX: identification of presenter	Used *M*s, *SD*s	−0.25	−0.02
Spencer & Raz (1994)	32	32	CN: cued recall of facts CX: general event identification, temporal order, color identification	Used *M*s, *SD*s	0.67	0.62
Zelinski & Light (1988)	96	96	CN: recognition of pictures CX: identification of spatial location	Used *M*s, *SD*s	0.92	1.25

[a] Averaged across retrieval effort, encoding effort, and material type.
[b] Assumed equal variance.

Appendix B

Reasons for Exclusion of Studies From Meta-Analysis and the Number of Studies ($N = 51$) for Each

Reason	No. studies
No measure of memory for context was included in the study	21
No measure of memory for content was included in the study	9
Measures of content and context were not separately derived	9
Measures of content and context were taken from measures derived from performance on different instruments	3
The study investigated primary or short-term memory	3
The mean age of older participants was less than 60 years	3
The mean age of younger participants was greater than 35 years	1
The design of the study did not allow for experimental control of content or context measures	2

Appendix C

Equations Used to Calculate and Evaluate Effect Sizes

Equation 1 shows the calculation of unbiased effect size (d):

$$d = c_n g, \tag{1}$$

where C_n is the correction factor for g, which is based on the sample size, n, of each group.

$$C_n = 1 - \frac{3}{4n_1 + 4n_2 - 9} \tag{2}$$

Equation 3 pertains to the calculation of the homogeneity statistic Q_T:

$$Q_T = \sum_{i=1}^{k} w_i(d_i - d.)^2. \tag{3}$$

Equations 4 through 6 show how to calculate the weighted average effect size ($d.$).

$$v = \frac{n_1 + n_2}{n_1 n_2} + \frac{d^2}{2(n_1 + n_2)} = \frac{2}{n}\left(1 + \frac{d^2}{8}\right). \tag{4}$$

$$w = \frac{1}{v}. \tag{5}$$

$$d. = \frac{\sum_{wd}}{\sum_{w}}. \tag{6}$$

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