In J.T.E. Richardson (Ed.) Counterpoints in Cognition: Working Memory and Human Cognition (pp. 66–88). Oxford, UK: Oxford Univ. Press. (1996)

3

Working Memory and Aging: Current Status of the Inhibitory View

Ellen R. Stoltzfus, Lynn Hasher, and Rose T. Zacks

The construct of working memory has become a central component of many models of cognitive functioning, including those developed in the areas of thinking, problem solving, and memory, as well as in most aspects of language processing, such as comprehension, production, and reading. Generally, working memory is conceptualized as a mental workspace consisting of activated memory representations that are available in a temporary buffer for manipulation during cognitive processing. These activated representations may or may not be available to consciousness, but they are usually thought to be above some threshold of activation (Baddeley, 1986, 1992; cf. Cowan, 1988, 1993). Working memory has both storage and processing functions, enabling both the temporary maintenance of active representations in memory and also the manipulation of these representations in the service of current processing demands. In tasks such as language comprehension, in which complex processing of current information is ongoing but in which continuity with previous information must be preserved at all times, efficient operation of both the processing and storage components of working memory is critical. Demands placed on working memory at any given time will, of course, vary across situations and across individuals who differ in expertise or cognitive abilities.

Although there is considerable agreement that working memory plays a critical role in cognitive processing, a lack of consensus exists among cognitive theorists as to how best to conceptualize working memory and the role it plays in different cognitive activities. In this chapter we first consider conceptualizations of working memory that stress its purported limited capacity, and then we turn to an alternative (first proposed by

Hasher & Zacks, 1988) that focuses on the inhibitory control of the contents of working memory. Following a review of the evidence relevant to this alternative, particularly evidence stemming from studies exploring adult age differences in attention, memory, and language, we shall conclude with a discussion of issues that are in need of further clarification and investigation.

Working Memory and the Limited-Capacity Assumption

Almost all conceptions of working memory assume that there is a limit in the extent to which working memory is able to hold and process information. However, despite its apparent widespread appeal, significant problems exist with the limited-capacity assumption, some of which relate to limited-capacity notions in general, whereas others relate to working memory in particular. With regard to the former, Allport (1989) and Navon (1984) among others have provided excellent critiques of the general notion of capacity limitations on cognitive processing, and it is not our wish to reiterate here all of the arguments put forward by these authors. Suffice it to say that there are both conceptual and empirical shortcomings to limited-capacity views. These include the vagueness of the central constructs and the failures of findings (for instance, from dual-task situations) to conform to reasonable predictions derived from the assumption of a capacity limitation on some central resource.

With respect to working memory, one problem is that the locus of the proposed limitation in the ability to hold and process information has been hotly debated. Virtually every possible aspect of working memory has been pinpointed as the capacity limitation by one investigator or another; these include storage capacity, amount of available activation, processing capacity, and ability to allocate resources to both processing and storage components (see, e.g., Engle, Cantor, & Carullo, 1992). After many years of research, no consensus has been reached as to the particular source of the working-memory capacity limitation.

Other difficulties for the limited working-memory capacity notion have become apparent in the actual quest to measure working memory in terms of both its storage capacity and its processing capacity. Thus far, considerable effort has failed to yield any measure or group of measures that are agreed to measure the capacity of working memory in an accurate and reliable manner. Related to this is the existence of conflicting evidence regarding whether particular working-memory measures tap into a domain-specific resource or a general resource. For example, although Daneman and Tardif (1987) concluded in favor of the domain-specific view, Engle et al. (1992) concluded that working memory was a general resource that served a wide variety of verbal and nonverbal cognitive tasks.

Nonetheless, because of its face validity and intuitive appeal, and because it has served as a productive framework in a number of different contexts, the limited-capacity tradition has survived despite the problems discussed above. Here, we briefly review some of the work exploring the possibility that individual differences among adults and group differences among adults of varying ages might be attributed to variations in their working-memory capacity.

Individual Differences in Working-Memory Capacity

One main path for verifying specific hypotheses about the way in which limited capacity affects cognitive functioning is to compare individuals or groups that are presumed to differ in working-memory capacity. The research strategy is to use some measure of working-memory capacity and to correlate performance on that task with performance on other cognitive tasks that are of interest, such as language-comprehension. This sort of approach has been used to study individual differences in language processing and group differences among, for example, younger and older adults, children of various ages, and patients with Alzheimer's disease.

As John Richardson mentioned in Chapter 1, the first task used in the language-comprehension literature to measure working-memory capacity was the "reading-span" task (Daneman & Carpenter, 1980). In this task, subjects are asked to read sets of sentences of moderate complexity and then to do two things: to comprehend each sentence and to remember the last word of each sentence (thus tapping both the processing and the storage components of working memory). "Reading span" is then measured by the largest set of sentences in which a subject is able consistently to remember the last word of each sentence.

The early work by Daneman and colleagues showed that their index of working-memory capacity predicted several performance measures related to verbal ability, including the verbal score in the Scholastic Aptitude Test (SAT), the accuracy in determining the referent of a pronoun, the accuracy in determining novel word meanings by using the surrounding context, and scores on items testing comprehension (Daneman & Carpenter, 1980, 1983). Correlations between reading span and the various language-comprehension performance scores were in the .70 to .90 range, with correlations between reading span and verbal SAT generally above .50. Other investigators, however, have not been so successful at finding such strong correlations. For example, among a small (and possibly unrepresentative) sample of papers (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Engle, Carullo, & Collins, 1991; Light & Anderson, 1985), the highest correlation between a version of the reading-span test and comprehension is about .54. In some instances (see Light & Anderson, 1985, Experiment 2), the correlations are not even statistically significant.

Another complication, which has arisen since the early research on working memory, involves conflicting findings on the predictive value of working-memory–span tasks (which involve both processing and storage components) versus simple span tasks (which mainly involve storage and are usually measured by digit or word span). Although Daneman (e.g., Daneman & Carpenter, 1980; Daneman & Tardif, 1987) has argued that simple span scores are not nearly as predictive as working-memory scores in a variety of tasks, others have more recently found that simple span scores can be as predictive as working-memory–span scores (see, for example, Engle et al., 1991).

Just, Carpenter, and their colleagues (e.g., Just & Carpenter, 1992; MacDonald, Just, & Carpenter, 1992) have recently correlated scores on the original working-memory–span tasks with performance on various language-processing tasks. The data are compelling in suggesting that the capacity of working memory accounts for much variance in the performance of young adults, at least in their population (undergraduates at Carnegie Mellon University). Despite this success in relating performance to the capacity of working memory, alternative explanations have been presented for these individual differences (see MacDonald & Perlmutter, 1993).

Group Differences in Working-Memory Capacity Associated with Aging

With regard to aging, the basic argument of capacity theories is that older adults exhibit poor performance across a wide variety of cognitive tasks because of the reduction in working memory that occurs with increasing age. This viewpoint predicts that older adults will have lower average scores on measures of working-memory capacity, and furthermore that the differences in working-memory capacity can account for age differences on the target cognitive tasks (so that, when working-memory capacity is partialed out, age will no longer exhibit a significant association with the level of performance). The support for the first of these predictions is fairly strong, but, even so, there are reports of failure to find age differences on tests of working-memory capacity (e.g., Hartley, 1986, 1993). Furthermore, even when age differences in the capacity of working memory are found, it is not always the case that age differences in performance on memory and language tasks are attributable to the working-memory differences (e.g., Hartley, 1986, 1993; Light & Anderson, 1985; see Light, 1991, for a review of the relevant literature on both of these points). A further complication is that there is a lack of consensus as to the specific aspect of working memory (i.e., storage, processing, or coordination mechanisms) that is compromised (cf. Craik & Jennings, 1992; Salthouse, 1990).

In sum, the literature on age-related performance differences, our central interest, has lent mixed support to the reduced-capacity approach. Despite the kinds of conceptual and empirical problems mentioned above, some authors (such as Craik & Jennings, 1992; Salthouse, 1990) continue to hold this up as a good model for generating and understanding research. However, others (Hasher & Zacks, 1988; Light, 1991) have called for alternative accounts. In our view, capacity theories, although both intuitively appealing and intermittently successful in accounting for a broad range of findings (at least on the surface), are ultimately not as productive as approaches that seek to reveal underlying processes. These processes (which may or may not be capacity-limited) will vary in their efficiency across individuals and groups and affect processing in complex and interesting ways that are not necessarily predicted by capacity views. We have generally found capacity explanations for individual as well as group differences to be unsatisfying, because there could be multiple reasons for capacity reductions and multiple ways in which these capacity reductions produce performance differences. In fact, we (Hasher & Zacks, 1988; Zacks & Hasher, 1994) have argued that other problems may be the underlying cause of what appears to be decreased capacity in older adults.

An Alternative View to Capacity

The failure of the capacity model of working memory to account satisfactorily for differences between older and younger adults' performance led Hasher and Zacks in 1988 to turn their attention from views that emphasized the sheer *capacity* of working memory to a new view emphasizing the *contents* of a working memory that might or might not be limited in size. At the time, Hasher and Zacks offered their view as an alternative to limited capacity; this is because they considered the notion of limited resources to be a problematic and possibly unnecessary assumption. At the very least, they considered capacity views to offer an incomplete explanation for patterns of performance. The alternative view developed by Hasher and Zacks was based on the idea that it was not the size of a working memory that would determine performance but how well the contents of the working-memory (or activated-memory) set represented the current task goals. If the activated information in memory were closely tied to the goals of the ongoing task, then performance would be good. If, on the other hand, the set of activated information included thoughts that were irrelevant to the task at hand, then the simultaneously processed relevant and irrelevant trains of thought would create a situation analogous to a divided-attention task.

A consequence of creating such a divided-attention situation is that comprehension and memory performance would be likely to suffer through several avenues. First, divided attention could create difficulties at encoding. "Cross talk" between concurrent streams of information would be likely to occur, especially if attempts were made to integrate irrelevant ideas with ongoing discourse. Because of these encoding complications, comprehension and retrieval would be less successful, either because the information to be retrieved was not sufficiently encoded or because the association of relevant and irrelevant material at the time of encoding created competition at retrieval among the relevant and irrelevant aspects of information. Competition could also cause slowed retrieval during the immediate memory searches that would be necessary to maintain coherence in the discourse (for example, searching for the referent of a pronoun). In addition, yet more retrieval interference would be likely if, at the time of retrieval, any further distractions were either internally generated or externally presented.

The key to successful processing, then, from Hasher and Zacks's viewpoint, is to allow relevant information to enter working memory, but to keep irrelevant information out of working memory. Moreover, because the nature of on-line processing ensures that information once relevant will sometimes become irrelevant as processing proceeds, the comprehender must work to remove that currently activated information from working memory in a routine, quick, and efficient manner. Hasher and Zacks (1988), therefore, suggested that the functioning of working memory was intimately tied to mechanisms of attentional selection. In particular, they postulated inhibitory processes that could accomplish the dual tasks of screening access to working memory and suppressing previously relevant, but currently irrelevant, information from working memory.

As we previously noted, Hasher and Zacks's inhibition view of working-memory processes arose in the context of accounting for adult age differences in memory and comprehension performance. There is extensive documentation in the aging literature of increased distractibility and susceptibility to perceptual interference in elderly adults. Compared with younger adults, older adults show elevated response times and errors in visual search when distractors are present in a display and there are no spatial cues to help them to focus their search (Madden, 1983; Plude & Hoyer, 1985; Rabbitt, 1965). Older adults show large Stroop interference effects, possibly because they are less able than younger adults to suppress the familiar response of reading a color word when asked to name the word's color (Cohn, Dustman, & Bradford, 1984; Comalli, Wapner, & Werner, 1962). In some cases, older adults are also more distracted than younger adults in "flanker" tasks, in which irrelevant information is visually presented in close proximity to relevant information (e.g., Cremer & Zeef, 1987; Shaw, 1991). Such findings of increased interference and general susceptibility to "noise" in the environment (Layton, 1975; Welford, 1958) led some researchers to suggest that an inhibitory process was impaired in the elderly (e.g., McDowd, Oseas-Kreger, & Fillion, 1995; Rabbitt, 1965).

Recent work has confirmed that elderly adults are impaired in one particular task that is thought to be a direct indicator of the inhibitory processes of attention. The task requires a simple selection response, but on some trials the item that previously served as a distractor becomes the current target. On these trials, younger adults show slower response times and errors compared with trials on which successive targets and distractors are unrelated (e.g., Dalrymple-Alford & Budayr, 1966; Neill, 1977; Tipper, 1985). This difference in responding has been attributed to the suppression of distractors, which results in making them temporarily less available as a response (Tipper, 1985). If elderly adults suffer from an inhibitory deficit, they should not show the suppression effect demonstrated by young adults, and this is just the pattern that has been obtained in several studies (Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane, Hasher, Stoltzfus, Zacks, & Connelly, in press; McDowd & Oseas-Kreger, 1991; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, 1991).[1] Hasher and Zacks (1988) suggested that the failure of inhibitory selection mechanisms might be pervasive in elderly adults' cognitive performance, impairing not only attention and perception but also memory, thinking, and language processing, by providing only a loose monitor of the contents of working memory. The ultimate consequence of poor inhibitory processing in elderly adults would be an increase in irrelevant or marginally relevant ideas in working memory, thus dividing attention, producing interference, and culminating in increased memory and comprehension failures.

Although the inhibition theory was devised as an explicit alternative to capacity theories, it is conceivable that it could be interpreted as a capacity view, in the sense that, when irrelevant information gains access to working memory, it leaves less "space" for the storage or processing of relevant information. In fact, it may be difficult to distinguish empirically between, on the one hand, performance limitations that result from a reduced capacity for relevant information caused by the maintenance of irrelevant information and, on the other hand, performance limitations that are the consequence of "cross talk" between concurrently activated relevant and irrelevant information in a working memory with no intrinsic capacity limit. It has also been suggested that inhibition might itself be a resource-limited process (e.g., Neumann & DeSchepper, 1992; and see Chapter 4 in this volume by Randall Engle), introducing another form of capacity limitation. The synthesis of inhibition and capacity views may turn out to be useful, in part because capacity notions by themselves are insufficient. We now turn to a summary of some of our recent work that has been motivated by the reduced-inhibition view.

Although failures in memory and comprehension are predicted by many theories of aging (including several resource theories), the inhibition framework makes unique predictions about age differences in performance. The major predictions are as follows:

1. *Greater breadth (or enrichment) of working-memory information.* Because suppression mechanisms are less effective in blocking entrance to working memory in older as opposed to younger adults, older adults should show evidence of *more* information becoming

active in working memory than younger adults. The additional active units might include irrelevant word meanings or associates, contextually inappropriate interpretations of sentences, daydreams, or personalistic items.

2. *Sustained activation (or maintenance) of thoughts.* Older adults should have difficulty eliminating information from working memory when it is activated but becomes irrelevant. Older adults should therefore show greater activation of previously relevant information, even, perhaps, when it is inconsistent with their current goals or other simultaneously active representations.
3. *Greater interference at encoding and retrieval.* The opportunity for competition among thoughts should be increased for older adults at the time of both encoding and retrieval because of the concurrent presence of irrelevant thoughts during both encoding and retrieval and also because of the linking of irrelevant thoughts to target information in memory.

We now review some recent evidence bearing on the above predictions. As will be seen, much of the evidence is consistent with the inhibition theory, although there are some limits to the findings and the theory. These will be discussed in the final section of this chapter.

Prediction 1: Greater Breadth or Enrichment of Working-Memory Information

Much indirect evidence exists for the prediction of greater enrichment of working memory through the inability to suppress extraneous information. For example, Connelly, Hasher, and Zacks (1991) presented passages with distracting text (in standard font) intermixed with the target text (in italics). As indicated by their reading times and their performance on comprehension items, older adults had greater difficulty reading the passages with distracting text. This suggests that older adults were having difficulty inhibiting the irrelevant text as they read the target text. But how exactly is this related to decrements in comprehension? A condition in which distracting text was semantically related to the target text is relevant here: Older adults showed particularly compromised speed and comprehension in this condition. In these circumstances, "irrelevant" information is actually marginally relevant information, and it appears to enter working memory and to interfere with target processing to a greater extent in older adults than in younger adults (who showed no performance difference between text-relevant and text-irrelevant passages). As the same distractors appeared repeatedly throughout a paragraph in this study, an additional source of difficulty might have arisen from the opportunity for distractors to become familiar to older adults and therefore to become very easily reactivated when they were encountered again.

Another finding indicating that older adults have difficulty suppressing nontarget information comes from research using the flanker task. In this task, subjects categorize a central word (or letter) that is flanked on either side by nominally irrelevant words (or letters). Consistent with the reduced-inhibition view, Shaw (1991) recently found that, although older adults showed the same amount of facilitation as did younger adults from flankers whose category membership was consistent with the target, they showed a greater degree of interference from flankers whose category membership was inconsistent with that of the target.

A more direct study of the enrichment of working memory explored the activation of information during sentence processing by examining the availability of various sentence endings. The study used materials and procedures similar to those employed by Schwanenflugel and colleagues (see Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985) to investigate the effects of sentence constraint on the number of sentence endings that were available to subjects. Stoltzfus (1992) presented younger and older adults with sentences that were missing their final word (for instance, "The landlord was faced with a strike by the ___________"). The availability of sentence endings was tested using a lexical decision response for words that were highly expected according to production norms (e.g., *tenants*) or relatively unexpected but quite appropriate for the context (e.g., *residents*). Lexical-decision response times were then compared with those in a control condition where subjects saw target words after a neutral context (strings of the letter *X*). Although younger adults showed priming only for the highly expected words, thus demonstrating a relatively narrow range of availability of endings, older adults showed priming for both types of endings, suggesting that a broader range of endings was available to them while processing the sentences.

Several studies of speech production have suggested that older adults also enrich their speech with a broader range of information than do younger adults. For example, older adults tend to produce more personalistic information and off-track comments in their narratives (Arbuckle & Gold, 1993; Gold, Andres, Arbuckle, & Schwartzman, 1988; Obler, 1980). These ideas may occur to younger adults as well, but they do not produce them as often as do older adults, perhaps because older adults cannot easily suppress such thoughts once they come to mind.

Prediction 2: Sustained Activation or Maintenance of Thoughts

The second prediction, that older adults should have sustained maintenance of activated information, should result from the difficulty in eliminating activated information that becomes irrelevant: In other words, they would fail to update working memory to reflect their current goals. The reading of garden-path passages represents one situation in which this ability to update is important. These passages begin by misleading their reader into making an inference that turns out to be false. For example, the reader might be led to believe that a character is on a hunting safari, when in fact he or she is on a photographic safari. In one such study, Hamm and Hasher (1992) presented various passages to younger and older adults and measured the availability of critical inferences at two points during the passages. Although older and younger adults performed in a similar manner on non-garden-path control passages, they showed a very different pattern of availability during passages that had a garden-path manipulation. For these passages, older adults were much more likely than younger adults to show activation of two separate, competing interpretations of the passage, despite the presentation of disambiguating information.

In addition to "on-line" evidence for the maintenance of information that should be rejected, there is evidence concerning the later retention of such information. Hartman and Hasher (1991) presented subjects with single sentence frames that had highly predictable endings. Subjects were instructed to generate an ending after reading a sentence frame, but were then sometimes presented with another ending to remember instead of their own, self-generated ending. In a task that, to subjects, appeared unrelated to the sentence-generation task, subjects were given an implicit memory test that tested memory for both generated but disconfirmed endings, and for the target endings that subjects had actually been instructed to remember in place of their own endings. Both older and younger adults showed memory for the target endings, but only older adults demonstrated memory for the disconfirmed endings. Hartman and Hasher concluded that the better memory shown by the older adults was a result of a compromised ability to suppress the disconfirmed endings.

A similar result arose in several experiments on directed forgetting carried out by Zacks, Radvansky, and Hasher (1994). Here, subjects were presented with lists of words, some of which they were instructed to remember, as well as others that they were instructed to forget. In a final free-recall task in which subjects were asked to recall the "forget" items as did well as the "remember" items, older adults tended to recall at least as many "forget" items as did younger adults, while showing much poorer recall of the "remember" items. This pattern suggests that older adults were less able to follow "forget" cues at encoding. In some cases, older adults in this study also showed increased numbers of intrusions from the previous lists when they attempted to recall each list's "remember" words during the experiment. Such a result is not surprising in the performance of older adults, who have been reported to show increased intrusions in the free recall of sentences (Stine & Wingfield, 1987), increased productions of already-produced responses (Koriat, Ben-Zur, & Sheffer, 1988; Whitaker, 1992), increased false alarms for semantic associates of previously presented words (Rankin & Kausler, 1979; Smith, 1975), and increased difficulty in changing a highly practised response pattern (e.g., Dulaney & Rogers, 1992; Hess, 1982, Experiment 3).

The inability to inhibit information that is no longer relevant has been targeted in another theory, which has been proposed to account for differences in verbal ability among young adults. Gernsbacher's (1990) "structure-building" framework assumes that general-suppression processes help comprehenders to build and to maintain an accurate and coherent text representation, and she has been quite successful in linking suppression efficiency to performance on various memory and comprehension tasks. Gernsbacher has shown, for example, that poor comprehenders maintain the inappropriate meanings of homographs longer than do good comprehenders (see Gernsbacher & Faust, 1991). The poor comprehenders in her studies appear to have no difficulty activating correct interpretations, but they are less efficient in suppressing candidate interpretations that turn out to be inappropriate. This pattern parallels the findings we see with younger and older adults.

Prediction 3: Greater Interference at Encoding and Retrieval

Data relevant to the prediction that the memory performance of older adults will show an increased sensitivity to interference effects at both encoding and retrieval come from our research using the "fan-effect" paradigm developed by Anderson (1974, 1983). In fan-effect experiments, subjects first learn a set of target facts, such as the following examples taken from Gerard, Zacks, Hasher, and Radvansky (1991): "The doctor took the car for a short test drive"; "The judge cut the apple pie into six pieces." In a subsequent speeded recognition test, subjects are asked to distinguish between the target facts and unstudied foil facts constructed from re-pairings of the subject and predicate phrases of the targets (e.g., "The doctor cut the apple pie into six pieces"). The fundamental finding, the fan effect, is tied to "fan size": The more facts learned about a particular concept (such as the doctor), the longer it takes to retrieve any one of those facts and usually the more errors are made.

Consistent with our expectations, Gerard et al. (1991) found that older adults showed much larger fan effects than did young adults in terms of both reaction times and errors. We attribute this outcome to the effects of reduced inhibition that occur both at encoding and at retrieval. To be specific, we believe that, at encoding, older adults are less able than younger adults to suppress irrelevant thoughts activated by the experimental materials, and that they may have a harder time constraining rehearsal to a single experimental item. Consequently, each experimental fact is likely to be associatively elaborated with additional information. At retrieval, this additional information is reactivated, thus creating problems for the older person in searching for the target information. In addition, older adults are likely to suffer more than young adults from additional irrelevant thoughts that may be elicited by the memory probes.

It may also be noted that, although there are some negative findings (cf. Kausler, 1990), the results of studies involving more traditional interference procedures (that is, retroactive and proactive interference) are, under certain circumstances at least, supportive of the notion that older adults show an enhanced sensitivity to interference from nontarget materials. These circumstances include the use of sensitive measures such as error analyses and reaction times and also experimental procedures that give the opportunity for significant amounts of interference. Under these conditions, older adults tend to show enhanced proactive and retroactive interference. A particularly interesting recent finding comes from a study by Kliegl and Lindenberger (1993), who used a paradigm in which subjects learned a sequence of paired-associate lists involving the re-pairing of the same items (in other words, an "A-B, A-Br" paradigm), and found that, even when the overall performance was equated across age groups, older adults showed an increase in intrusion errors consisting of responses that had been correct on the preceding lists (see Gerard et al., 1991, and Kane & Hasher, in press, for other relevant evidence).

Further Considerations and Future Directions

Taken as a whole, the evidence for the inhibition view is encouraging. Older adults appear to have difficulty inhibiting irrelevant information whether it is internally generated (e.g., during speech) or externally presented (e.g., when visual distractions are present during reading). They further have difficulty rejecting activated information when, under a variety of circumstances, it later becomes irrelevant. These circumstances lead to increased levels of interference at both encoding and retrieval.

Our model-building approach shares with that of Baddeley (1992) the strategy of using new data to influence the model's development. To this end, several issues regarding current findings need to be considered. First, we will address an empirical problem of separating broad activation from the sustained maintenance of activation (Predictions 1 and 2 above). Second, we will consider the issue of memory for irrelevant information, and the conflicting data in the literature about whether older adults are more likely to remember irrelevant information. Next, we will consider a related problem, that of measuring performance in the case of "relevant" and "irrelevant" information, since the determination of relevance may be difficult, especially given the potentially different goals of younger and older adults. Finally, we will discuss the functions of inhibition and situations where inhibitory deficits might lead to performance advantages.

Empirical Separability of Predictions 1 and 2

Hasher and Zacks (1988) considered the enrichment of working memory and the sustained maintenance of activation to be two separate consequences of inhibitory failure, but these might be difficult to separate empirically. The root of the problem is that addressing this issue requires precise knowledge of the time course of activation and suppression for younger and older adults in each task. This sort of on-line testing is difficult to implement (in studies of text processing, for example), and hence we have little evidence to distinguish clearly between broader initial activation in older adults and the failure of older adults subsequently to suppress information that is initially activated for both younger and older adults.

It should also be noted that there is a body of evidence against the initial-breadth prediction. For example, using word-production measures and single-word priming measures, both the strength and the breadth of the associations produced by younger and older adults are generally found to be the same (e.g., Burke & Peters, 1986; Burke, White, & Diaz, 1987; Howard, 1980, 1983; Howard, McAndrews, & Lasaga, 1981). There is also some evidence that multiple senses of homographs are not differentially activated in older and younger adults (Burke & Harrold, 1988). Finally, studies that have used introspective methods for determining the number of task-unrelated thoughts generated by young and older adults have suggested that older adults actually experience fewer task-unrelated thoughts and daydreams than do younger adults (e.g., Giambra, 1989).

On the other hand, one new line of work that is consistent with the broad-activation prediction assesses semantic priming under strict and short deadlines (Laver, 1992, 1994). Even under these brief and demanding circumstances, older adults show more priming than do younger adults. It might be that the greater number of alternatives activated by older adults increases the likelihood of a match between the prime and the target, thus producing the larger priming effects seen in older adults. In summary, evidence for the breadth prediction is more controversial than evidence for the failure-to-suppress prediction. It might be premature, however, to conclude that there is substantial evidence against a broad-spread activation view without further research. It is increasingly clear that small differences in the experiment-wide composition of materials can alter the strategies of younger subjects (e.g., Stoltzfus & Hasher, 1990; Tweedy, Lapinski, & Schvaneveldt, 1977), and this may also hold true for older adults. In addition, further exploration of the time course of processing in each task will be useful for resolution of this issue.

Memory for Irrelevant Information

If older adults process more irrelevant information, or if they experience more sustained activation of this information, it follows that they should not only have decreased memory for target information but should also have better memory for irrelevant information (proportionately, at least) than younger adults. However, the empirical evaluation of this prediction is complicated by the fact that the increased retrieval interference predicted for older adults should affect memory for both relevant and irrelevant information. With respect to target information, the impact of an increased sensitivity to interference is demonstrated by the following pattern of data, for which there is ample evidence: Older adults remember less target information on explicit memory tasks (see Kausler, 1990, for an overview), but they show a smaller or nonexistent impairment on implicit tasks that may involve minimal retrieval interference (e.g., Howard, 1988; Light & Singh, 1987).

The findings regarding memory for irrelevant information are likewise dependent upon the type of test used to measure memory (see also Hartman & Dusek, 1994). To illustrate this point, we return to a study that we described earlier, in which Connelly et al. (1991) asked subjects to read stories presented amid distracting text printed in a different typeface. Older adults showed a greater slowdown in reading time than young adults when distraction was present during reading, which suggests that they were paying more attention to the distracting words. However, younger and older adults showed equal retention for distractor items from the reading task when those distractor items were used as foil answers in a series of multiple-choice questions. In fact, some studies have found that older adults remember *less* distracting information than do younger adults when explicit memory tests are used (e.g., Kausler, 1990; Kausler & Kleim, 1978).

On the other hand, Shaw, Rypma, and Toffle (1992) recently used a procedure similar to that employed in the study by Connelly et al. (1991), and they found that older adults actually showed better memory for distractors using a priming measure in an implicit memory task, suggesting that older adults will show better memory for irrelevant information than will younger adults under certain circumstances, including those that minimize retrieval interference.

Patterns of memory performance within tests of implicit memory and within tests of explicit memory throughout the aging literature are not entirely consistent across studies, perhaps reflecting the mix of direct and indirect retrieval processes that together determine performance on a particular task (e.g., Jacoby, 1991). Close examination of the retrieval demands involved in different memory tasks may help to resolve this issue (see Hartman & Dusek, 1994). Nevertheless, there certainly appears to be evidence that older people show relatively better memory on tests that do not require explicit retrieval, and further that they may even outperform younger adults when irrelevant information is the focus of retrieval (see Hartman & Dusek, 1994; Hartman & Hasher, 1991; Shaw et al., 1992).

What do these differing results on various memory tests suggest about the nature of retrieval processes or representations in working memory for younger as compared to older adults? It would be expected that irrelevant information, even when activated, should be less thoroughly processed and less likely to enter rehearsal cycles, since it is not strongly supported by the context. Therefore, irrelevant information should be less likely to be remembered than target information, at least in explicit tests. Implicit tests, especially perceptually driven ones, are less sensitive to interference or competition at retrieval (Graf & Schacter, 1987) and are less sensitive to semantic encoding manipulations (Blaxton, 1989) than are explicit tests, and thus they might be more likely to pick up activation of irrelevant information in elderly adults. It is important to note that, although irrelevant information might not be available for explicit retrieval in older adults because of inappropriate or inadequate encoding and rehearsal, it might still interfere with the explicit retrieval of other relevant information.

What Is "Irrelevant" Information?

Thus far in our discussion of performance on various memory and language tasks we have assumed that the goals of the experimenter are generally the goals of the experimental subjects. This assumption is important to note, because selection of information to be attended to (and therefore the contents of working memory) will be determined by the goals of the reader or listener. In a text-comprehension situation, for example, we generally assume that the reader's goal is to comprehend the passage being read. However, the reader might be concerned about how the current text relates to his or her youngest daughter or how the moral of a story applies to one's own life. The reader could also be maintaining thoughts that are important to that individual but have little or nothing to do with the text, such as whether he or she should make lasagna or pizza for dinner. In each case, the contents of working memory will be somewhat different, reflecting the goals of the reader, who is also, of course, a person with individual values and interests. In this sense, nothing in working memory is ever truly "irrelevant," because the goals of the reader will always be reflected in the reader's thoughts. Thus, for example, both depressed (Ellis & Ashbrook, 1988) and anxious individuals (Eysenck, 1992) may have many irrelevant thoughts in mind, but these thoughts are only irrelevant by the standards of those whose goals are uninfluenced by these concerns.

This acknowledgment of the individual goals of the reader was particularly important to the theory of Hasher and Zacks (1988), as the populations compared in aging research are likely to have different goals in many situations, such as psychological experiments (LaBouvie-Vief & Blanchard-Fields, 1982). This may, in turn, cause older adults to consider a wider range of information to be relevant to their task. If older adults are bringing different values and therefore broader goals to the reading situation, they will necessarily have different information (and perhaps, as we have argued, more information) activated in working memory. Thus, distinguishing between the performance patterns associated with aging per se and performance determined by age differences in goals becomes a concern. This can probably best be handled experimentally by using, for example, text materials that are of special interest to older adults, as well as by studying the impact of inhibitory mechanisms upon performance in nondiscourse tasks, where goals of the sort identified by LaBouvie-Vief and Blanchard-Fields (1982) may play less of a role.

Beyond particular sets of goals, several other factors might influence which information gains access to and is maintained in working memory. For example, the function of the presented information may be important: If the information is clearly irrelevant when presented, older adults might find it easier to reject such information, as opposed to situations in which information is initially thought to be relevant, and only later is identified as irrelevant (as is the case in many of the studies discussed here). The spatial separation of the relevant and irrelevant information (especially when that separation may be used as an early cue to determine allocation of attention) also appears to benefit older adults' selection of target information (e.g., Carlson, Hasher, Connelly, & Zacks, 1995; Madden, 1983; Plude & Hoyer, 1985) and therefore may also affect patterns of memory for irrelevant information in older adults. Recent data from our laboratory have suggested another variable that may moderate the ability to suppress previously activated information: synchrony between the time of day when a subject is tested, and the particular subject's optimal time-of-day tendency, as measured by the Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976). When older adults are tested at their nonoptimal time of day (generally the late afternoon), they may have more difficulty suppressing irrelevant information than at their optimal time of day (generally the morning) (May, Hasher, & Bhatt, 1994).

Potential Functions of Reduced Inhibition

Although we have generally focused on the difficulties arising from reduced inhibitory abilities (and they seem substantial and pervasive), there could be benefits as well, which we have only begun to pursue. Actually, in several of the tasks described in this chapter, age differences occur in the form of *benefits* (or a lack of decrement) in performance in critical conditions. For example, the basic finding in "negative-priming" tasks used to tap inhibitory processes is a slowdown in response time when a current response has been suppressed on an earlier trial. Older adults show no such response-speed decrement, presumably because they have not previously suppressed the current response. Such findings are interpreted as a decrement in inhibitory processes, and they are used to explain many of the negative cognitive effects of aging, but in these particular instances the lack of inhibition actually leads to performance advantages.

Although the negative-priming task seems unlike real situations, the results suggest that situations in which "irrelevant" information becomes relevant are places to look for performance advantages for older adults. Such situations might include garden-path passages, where keeping active those interpretations that were previously selected against would be an advantage if they were to become relevant again. Decision making might also offer situations in which performance could be enhanced if subjects did not eliminate or inhibit alternative choices prematurely.

The enrichment of the working memories of elderly adults that results in interference and memory failure might be another source of benefits for older adults. Discourse (including, potentially, lectures) may be more interesting if personalistic anecdotes and other "extraneous" information are routinely included. In fact, evidence shows that older adults are judged to tell stories of higher quality than younger adults (see Kemper, Rash, Kynette, & Norman, 1990; Mergler, Faust, & Goldstein, 1985; Pratt & Robins, 1991). Older adults might also be more likely to take multiple perspectives or to see multiple interpretations of a problem or a social situation once they are activated, which can often be an advantage, and this may be related to what we commonly refer to as "wisdom" (Baltes & Staudinger, 1993). The routine maintenance of all sorts of enriched information from various sources may, under certain circumstances, lead to the increased integration of ideas. Indeed, evidence shows that older adults are more integrative in their interpretations of metaphors than are young adults (Boswell, 1979).

The idea that processing benefits may be accounted for by the same cognitive mechanisms that produce processing deficits is an appealing one. Inhibitory efficiency may be useful in exploring all types of performance differences, whether those related to aging or other group or individual differences. In fact, theories involving inhibitory mechanisms have been proposed to explain various aspects of the performance of young adults (Gernsbacher, Varner, & Faust, 1990; and see Chapter 4 in this volume by Randall Engle), schizophrenics (Beech, Powell, McWilliams, & Claridge, 1989; Cohen & Servan-Schreiber, 1992), patients with frontal-lobe damage (Dempster, 1992), and both normal and abnormal children (Bjorklund & Harnishfeger, 1990; Pennington, Groisser, & Welsh, 1993). Indeed, though the inhibition theory that we have described here was developed in the context of explaining age differences, it can be seen (and indeed was always intended) as a more general cognitive framework for understanding the role of working memory in determining performance across a broad range of cognitive tasks and subject populations.

Acknowledgments

We gratefully acknowledge the support of grant RO1 AGO4306 from the National Institute on Aging.

Note

1. We are focusing here on identity suppression tasks: That is, on tasks in which subjects must respond to the identity of a target (e.g., by naming it). Tasks that require subjects to respond to the location of a target show a different pattern. It has been suggested that this reflects the existence of separate visual processing systems concerned with object location and object identity, and that these systems show a differential decline with age (see Connelly & Hasher, 1993). There are, however, some circumstances under which older adults show significant negative priming of identity (May, Kane, & Hasher, 1995; Sullivan & Faust, 1993). These circumstances appear to involve situations in which basic inhibitory processes are

supplemented by other processes (such as backward retrieval) occurring during a multiply determined task (see May et al., 1995).

References

Allport, A. (1989). Visual attention. In M. I. Posner (Ed.), *Foundations of cognitive science* (pp. 631–682). Cambridge, MA: MIT Press.

Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology, 6*, 451–474.

Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior, 22*, 261–295.

Arbuckle, T. Y., & Gold, D. P. (1993). Aging, inhibition, and verbosity. *Journal of Gerontology: Psychological Sciences, 48*, P225–P232.

Baddeley, A. (1986). *Working memory*. Oxford: Oxford University Press.

Baddeley, A. (1992). Is working memory working? The fifteenth Bartlett lecture. *Quarterly Journal of Experimental Psychology, 44A*, 1–31.

Baddeley, A., Logie, R., Nimmo-Smith, I., & Brereton, N. (1985). Components of fluent reading. *Journal of Memory and Language, 24*, 119–131.

Baltes, P. B., & Staudinger, U. M. (1993). The search for a psychology of wisdom. *Current Directions in Psychological Science, 2*(3), 75–80.

Beech, A., Powell, T., McWilliams, J., & Claridge, G. (1989). Evidence of reduced "cognitive inhibition" in schizophrenia. *British Journal of Clinical Psychology, 28*, 109–116.

Bjorklund, D. F., & Harnishfeger, K. K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10*, 48–71.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 657–688.

Boswell, D. A. (1979). Metaphoric processing in the mature years. *Human Development, 22*, 373–384.

Burke, D. M., & Harrold, R. M. (1988). Automatic and effortful semantic processes in old age: Experimental and naturalistic approaches. In L. L. Light & D. M. Burke (Eds.), *Language, memory, and aging* (pp. 100–116). New York: Cambridge University Press.

Burke, D. M., & Peters, L. (1986). Word associations in old age: Evidence for consistency in semantic encoding during adulthood. *Psychology and Aging, 1*, 283–292.

Burke, D. M., White, H., & Diaz, D. L. (1987). Semantic priming in young and older adults: Evidence for age-constancy in automatic and attentional processes. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 79–88.

Carlson, M. C., Hasher, L., Connelly, S. L., & Zacks, R. T. (1995). Aging, distraction, and the benefits of predictable location. *Psychology and Aging, 10*, 427–436.

Cohen, J. D., & Servan-Schreiber, D. (1992). Context, cortex, and dopamine: A connectionist approach to behavior and biology in schizophrenia. *Psychological Review, 99*, 45–77.

Cohn, N. B., Dustman, R. E., & Bradford, D. C. (1984). Age-related decrements in Stroop color test performance. *Journal of Clinical Psychology, 40*, 1244–1250.

Comalli, P. E., Jr., Wapner, S., & Werner, H. (1962). Interference effects of Stroop color-word test in childhood, adulthood, and aging. *Journal of Genetic Psychology*, *100*, 47–53.

Connelly, S. L., & Hasher, L. (1993). Aging and the inhibition of spatial location. *Journal of Experimental Psychology: Human Perception and Performance*, *19*, 1238–1250.

Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging*, *6*, 533–541.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. *Psychological Bulletin*, *104*, 163–191.

Cowan, N. (1993). Activation, attention, and short-term memory. *Memory & Cognition*, *21*, 162–167.

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

Cremer, R., & Zeef, E. J. (1987). What kind of noise increases with age? *Journal of Gerontology*, *42*, 515–518.

Dalrymple-Alford, E. C., & Budayr, B. (1966). Examination of some aspects of the Stroop color-word test. *Perceptual and Motor Skills*, *23*, 1211–1214.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450–466.

Daneman, M., & Carpenter, P. A. (1983). Individual differences in integrating information between and within sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*, 561–583.

Daneman, M., & Tardif, T. (1987). Working memory and reading skill reexamined. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 491–508). Hove, UK: Erlbaum.

Dempster, F. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, *12*, 45–75.

Dulaney, C., & Rogers, W. (1992). *The effects of environmental support on age differences in ignoring distraction in reading*. Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Ellis, H. C., & Ashbrook, P. W. (1988). Resource allocation model of the effects of depressed mood states on memory. In K. Fiedler & J. Forges (Eds.), *Affect, cognition, and social behavior* (pp. 25–43). Göttingen, Germany: Hogrefe.

Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 972–992.

Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual differences in working memory for comprehension and following directions. *Journal of Educational Research*, *84*, 253–262.

Eysenck, M. W. (1992). *Anxiety: The cognitive perspective*. Hove, UK: Erlbaum.

Gerard, L., Zacks, R. T., Hasher, L., & Radvansky, G. A. (1991). Age deficits in retrieval: The fan effect. *Journal of Gerontology: Psychological Sciences*, *46*, P131–P136.

Gernsbacher, M. A. (1990). *Language comprehension as structure building*. Hillsdale, NJ: Erlbaum.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 245–262.

Gernsbacher, M. A., Varner, K. R., & Faust, M. E. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 430–445.

Giambra, L. M. (1989). Task-unrelated-thought frequency as a function of age: A laboratory study. *Psychology and Aging, 4*, 136–143.

Gold, D., Andres, D., Arbuckle, T., & Schwartzman, A. (1988). Measurement and correlates of verbosity in elderly people. *Journal of Gerontology: Psychological Sciences, 43*, P27–P33.

Graf, P., & Schacter, D. (1987). Selective effects of interference on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 45–53.

Hamm, V. P., & Hasher, L. (1992). Age and the availability of inferences. *Psychology and Aging, 7*, 56–64.

Hartley, J. T. (1986). Reader and text variables as determinants of discourse memory in adulthood. *Psychology and Aging, 2*, 150–158.

Hartley, J. T. (1993). Aging and prose memory: Tests of the resource-deficit hypothesis. *Psychology and Aging, 8*, 538–551.

Hartman, M., & Dusek, J. (1994). Direct and indirect memory tests—what they reveal about age-differences in interference. *Aging and Cognition, 1*, 292–309.

Hartman, M., & Hasher, L. (1991). Aging and suppression: Memory for previously relevant information. *Psychology and Aging, 6*, 587–594.

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. A. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 163–169.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). San Diego, CA: Academic Press.

Hess, T. M. (1982). Visual abstraction processes in young and old adults. *Developmental Psychology, 18*, 68–81.

Horne, J., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology, 4*, 97–110.

Howard, D. V. (1980). Category norms: A comparison of the Battig and Montague (1969) norms with the responses of adults between the ages of 20 and 80. *Journal of Gerontology, 35*, 225–231.

Howard, D. V. (1983). The effects of aging and degree of association on the semantic priming of lexical decisions. *Experimental Aging Research, 9*, 145–151.

Howard, D. V. (1988). Implicit and explicit assessment of cognitive aging. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development and adulthood: Progress in cognitive development research* (pp. 3–37). New York: Springer-Verlag.

Howard, D. V., McAndrews, M. P., & Lasaga, M. I. (1981). Semantic priming of lexical decisions in young and old adults. *Journal of Gerontology, 36*, 707–714.

Jacoby, L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30*, 513–541.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*, 122–149.

Kane, M. J., & Hasher, L. (in press). Interference. In G. Maddox (Ed.), *Encyclopedia of Aging*, second edition. New York: Springer.

Kane, M. J., Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Connelly, S. L. (1994). Inhibitory attentional mechanisms and aging. *Psychology and Aging*, *9*, 103–112.

Kausler, D. H. (1990). *Experimental psychology, cognition, and human aging* (2nd ed.). New York: Springer-Verlag.

Kausler, D. H., & Kleim, D. M. (1978). Age differences in processing relevant versus irrelevant stimuli in multiple-item recognition learning. *Journal of Gerontology*, *33*, 87–93.

Kemper, S., Rash, S. R., Kynette, D., & Norman, S. (1990). Telling stories: The structure of adults' narratives. *European Journal of Cognitive Psychology*, *2*, 205–228.

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

Koriat, A., Ben-Zur, H., & Sheffer, D. (1988). Telling the same story twice: Output monitoring and age. *Journal of Memory and Language*, *27*, 23–39.

Labouvie-Vief, G., & Blanchard-Fields, F. (1982). Cognitive ageing and psychological growth. *Ageing and Society*, *2*, 183–209.

Laver, G. D. (1992). *A speed-accuracy analysis of semantic priming effects in young and older adults*. Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Laver, G. D. (1994). *Vocabulary and short-term memory span as mediators of the speed of semantic priming in young and older adults*. Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Layton, B. (1975). Perceptual noise and aging. *Psychological Bulletin*, *82*, 875–883.

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

Light, L. L., & Anderson, P. A. (1985). Working-memory capacity, age, and memory for discourse. *Journal of Gerontology*, *40*, 737–747.

Light, L. L., & Singh, A. (1987). Implicit and explicit memory in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *13*, 531–541.

MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology*, *24*, 56–98.

MacDonald, M. C., & Perlmutter, N. J. (1993, November). *Probabilistic constraints and working memory capacity in syntactic ambiguity resolution*. Paper presented at the annual meeting of the Psychonomic Society, Washington, DC.

Madden, D. J. (1983). Aging and distraction by highly familiar stimuli during visual search. *Developmental Psychology*, 19, 499–507.

May, C. P., Hasher, L., & Bhatt, A. (1994). *Time of day affects susceptibility to misinformation in younger and older adults*. Paper presented at the North Carolina Cognition Conference, Winston-Salem, NC.

May, C. P., Kane, M. J., & Hasher, L. (1995). Determinants of negative priming. *Psychological Bulletin*, *118*, 35–54.

McDowd, J. M., & Oseas-Kreger, D. M. (1991). Aging, inhibitory processes, and negative priming. *Journal of Gerontology: Psychological Sciences*, *46*, P340–P345.

McDowd, J. M., Oseas-Kreger, D. M., & Fillion, D. L. (1995). Inhibitory processes in cognition and aging. In F. N. Dempster & C. J. Brainerd (Eds.), *Interference and inhibition in cognition* (pp. 363–400). San Diego, CA: Academic Press.

Mergler, N., Faust, M., & Goldstein, M. (1985). Storytelling as an age-dependent skill. *International Journal of Aging and Human Development, 20*, 205–228.

Navon, D. (1984). Resources—a theoretical soup stone? *Psychological Review, 91*, 216–234.

Neill, W. T. (1977). Inhibitory and facilitatory processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 444–450.

Neumann, E., & DeSchepper, B. G. (1992). An inhibition-based fan effect: Evidence for an active suppression mechanism in selective attention. *Canadian Journal of Psychology, 46*, 1–40.

Obler, L. (1980). Narrative discourse style in the elderly. In L. Obler & M. Albert (Eds.), *Language and communication in the elderly* (pp. 75–90). Lexington, MA: Heath.

Pennington, B. F., Groisser, D., & Welsh, M. C. (1993). Contrasting cognitive deficits in attention deficit hyperactivity disorder versus reading disability. *Developmental Psychology, 29*, 511–523.

Plude, D. J., & Hoyer, W. J. (1985). Attention and performance: Identifying and localizing age deficits. In N. Charness (Ed.), *Aging and human performance* (pp. 47–99). New York: Academic Press.

Pratt, M. W., & Robins, S. L. (1991). That's the way it was: Age differences in the structure and quality of adults' personal narratives. *Discourse Processes, 14*, 73–85.

Rabbitt, P.M.A. (1965). An age decrement in the ability to ignore irrelevant information. *Journal of Gerontology, 20*, 233–238.

Rankin, J. L., & Kausler, D. H. (1979). Adult age differences in false recognitions. *Journal of Gerontology, 34*, 58–65.

Salthouse, T. A. (1990). Working memory as a processing resource in cognitive aging. *Developmental Review, 10*, 101–124.

Schwanenflugel, P. J., & LaCount, K. (1988). Semantic relatedness and the scope of facilitation for upcoming words in sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 344–354.

Schwanenflugel, P. J., & Shoben, E. J. (1985). The influence of sentence constraint on the scope of facilitation for upcoming words. *Journal of Memory and Language, 24*, 232–252.

Shaw, R. J. (1991). Age-related increases in the effects of automatic semantic activation. *Psychology and Aging, 6*, 595–604.

Shaw, R. J., Rypma, B., & Toffle, C. (1992). *The effects of environmental support on age differences in ignoring distraction in reading.* Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Smith, A. D. (1975). Partial learning and recognition memory in the aged. *International Journal of Aging and Human Development, 6*, 359–365.

Stine, E. L., & Wingfield, A. (1987). Process and strategy in memory for speech among younger and older adults. *Psychology and Aging, 2*, 272–279.

Stoltzfus, E. R., & Hasher, L. (1990). *Individual differences in breadth of facilitation for high-constraint sentence completions.* Paper presented at the meeting of the Psychonomic Society, New Orleans, LA.

Stoltzfus, E. R. (1992). *Aging and breadth of availability during language processing.*

Unpublished doctoral dissertation. Department of Psychology, Duke University.

Stoltzfus, E. R., Hasher, L., Zacks, R. T., Ulivi, M. S., & Goldstein, D. (1993). Investigations of inhibition and interference in younger and older adults. *Journal of Gerontology: Psychological Sciences*, *48*, P179–P188.

Sullivan, M. P., & Faust, M. E. (1993). Evidence for identity inhibition and interference in younger and older adults. *Psychology and Aging*, *8*, 589–598.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, *37A*, 571–590.

Tipper, S. P. (1991). Less attentional selectivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society*, *29*, 45–47.

Tweedy, J. R., Lapinski, R. H., & Schvaneveldt, R. W. (1977). Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory & Cognition*, *5*, 84–89.

Welford, A. T. (1958). *Aging and human skill.* Oxford: Oxford University Press.

Whitaker, H. A. (1992). Early effects of normal aging on perseverative and non-perseverative prefrontal measures. *Developmental Neuropsychology*, *8*, 99–114.

Zacks, R. T., & Hasher, L. (1994). Directed ignoring: Inhibitory regulation of working memory. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory mechanisms in attention, memory, and language* (pp. 241–264). San Diego, CA: Academic Press.

Zacks, R. T., Radvansky, G. A., & Hasher, L. (in press). Studies of directed forgetting in older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.