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9 Capacity theory and the processing of inferences

Rose T. Zacks and Lynn Hasher

The study of adult age differences in comprehension of and memory for text is a now burgeoning enterprise in cognitive gerontology, in part because of the potential for direct application of the findings to everyday life. To date, the work on discourse processing suggests the existence of age deficits of varying magnitudes, deficits that are largely quantitative rather than qualitative in nature. The work thus suggests that older adults use the same processing mechanisms as younger adults but with poorer results (e.g., Mandel & Johnson, 1984; Zelinski, Light, & Gilewski, 1984).

Beyond this summary the literature yields few simple generalizations; indeed, the findings on any given variable (e.g., educational level) tend to be complex and inconsistent. Consider the literature on the recall of ideas that differ in their importance to the meaning structure of the text. The usual finding with young adults (called the "levels effect") is that the probability of recalling information from text is directly related to the information's importance level in the text as defined by a model (e.g., Kintsch's, 1974) of the hierarchical structure of that text. When young and elderly adults have been compared, different experiments have produced contradictory results (for a recent review, see Zelinski et al., 1984; see also Cohen, this volume). The most frequent findings are (1) parallel levels effects for younger and older adults (e.g., Zelinski et al., 1984); or (2) an exaggerated levels effect for the older adults, with the greatest age deficit seen at low importance levels (e.g., Dixon, Hultsch, Simon, & von Eye, 1984, for high verbal ability subjects; Spilich, 1983). However, there is also an occasional finding of a diminished levels effect for older adults with the greatest age deficit at high importance levels (e.g., Dixon et al., 1984, for low verbal ability subjects).

Conflicting results of this sort suggest the likelihood that additional variables are operating. In the case of the levels effect, such variables as education, verbal ability, and characteristics of the experimental texts (e.g., the familiarity of the text structure and/or its content) might mediate the variable aging trends (Dixon et al.,

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1984; Meyer & Rice, 1981). The suggestion that such variables interact with age differences is consistent with Jenkins's (1979) tetrahedral model of memory which argues that memory performance in a particular situation is a joint function of the characteristics of the subjects, of the materials they are required to remember, of the acquisition conditions, and of the criterial tasks. Indeed, Jenkins's model has been used in attempts to organize the findings on age differences in memory for both nonstructured and prose materials (Craik & Byrd, 1982; Hultsch & Dixon, 1984).

We are sympathetic with the general goals of identifying and classifying the multiple factors that control age differences in memory for text. However, we believe that pursuit of these goals will benefit from theoretical analyses which indicate the specific characteristics of subjects, materials, and tasks that might be functional in a particular situation. Thus, we chose a different approach to the general problem of age differences in discourse comprehension and memory.

The theoretical orientation guiding our research on discourse processing derives from limited-capacity attention theory (Kahneman, 1973). We began our research program with a general limited-capacity framework which made few specific claims about either the nature of capacity constraints on text processing or age differences. The initial framework and its associated research led us to elaborate on our capacity model in such a way as to increase the precision of our analysis of age differences in discourse processing. In this paper we trace the development of our thinking by reporting on a line of research that at first seemed to support and then to constrain the value of our initial general-capacity model. We also outline our elaborated view on which future research will be based.

The general-capacity theory and age differences in discourse processing

Two central assumptions of any limited-capacity model based on Kahneman's (1973) ideas are that (1) information processing is constrained by the amount of cognitive capacity (or mental resources) available at a given moment; and (2) that cognitive activities vary in the mental resources they require for maximal performance. In particular, automatic processes require very minimal amounts of capacity whereas effortful processes require significant resources (Hasher & Zacks, 1979, 1984). The fundamental aging assumption of a capacity-based theory of adult age differences in cognition is that available capacity declines with advancing age (e.g., Craik, 1983; Craik & Rabinowitz, 1983, 1984; Hasher & Zacks, 1979, 1984). The negative impact of this decline in mental resources should be minimal for automatic processes and should be increasingly severe the more demanding of capacity a particular effortful cognitive activity is.

Probably the most well known capacity-decline model of aging deficits in cognition is that of Craik and his colleagues (e.g., Craik, 1983; Craik & Byrd, 1982; Craik & Rabinowitz, 1983, 1984). This view assumes that aging deficits are due to a reduction in the "processing resources" needed to energize mental operations. For memory encoding, the major consequence of this reduction of resources is impaired semantic processing of to-be-remembered stimuli. Craik and his colleagues do not assume an absolute deficiency of semantic processing in older adults. The encoding of general, stereotypical aspects of meaning is preserved because the activation of these semantic attributes is largely automatic. However, the reduced processing resources do result in a diminished degree of elaboration and precision of semantic processing: Processing yielding rich, distinctive, and precise memories "is effortful and requires greater amounts of processing resources than [older adults] have available" (Craik, 1983, p. 112). A similar analysis applies to retrieval operations. The reduced processing resources of older adults result in a decrease in the occurrence of self-initiated and effortful retrieval operations. Where such operations are essential for good performance (e.g., free-recall tests), age differences will be seen, but where effortful retrieval operations are largely bypassed by strong environmental support for retrieval (e.g., perceptual learning tasks), age differences will be small or nonexistent.

Various findings, mainly from list memory experiments, support Craik's aging model. These include results indicating that young adults whose capacity for a target task is reduced by having them operate under divided attention constraints perform similarly to older adults (Rabinowitz, Craik, & Ackerman, 1982), and findings of relatively small age differences when the learning materials, the orienting task, and the memory test "drive" or "force" effective processing at encoding and retrieval (for a summary, see Craik, 1983). Findings from our laboratories are also consistent, at least in broad outline, with a reduced-capacity view of adult age differences in cognition: On the one hand, we have found no age differences in a memory task dependent on automatic encoding mechanisms (Attig & Hasher, 1980); on the other hand, we have obtained a significant age deficit in a memory task dependent on effortful processing (Zacks, 1982). Such findings, together with our own theoretical framework for cognitive processes (Hasher & Zacks, 1979, 1984), encouraged us to use a capacity model in our studies of discourse comprehension in older adults. (Cohen, this volume, also discusses capacity-based models of age differences in cognition.)

Application of a general-capacity framework to discourse processing

The value of capacity accounts of aging effects depends on the identification of mental activities that vary in their demands on cognitive capacity. Such identification is the basis of specific predictions of age-sensitive and age-insensitive cognitive operations. Because discourse processing clearly involves the coordinated occurrence of multiple-component processes which vary widely in their demands on cognitive capacity (cf. LaBerge & Samuels, 1974; Stanovich & West, 1983), this area seems to us to provide an ideal arena in which to test capacity models of adult age differences. Comparisons can be made between processes such as that of lexical access which tend to place minimal demands on capacity (Stanovich & West, 1983) and processes such as that of generating an anaphoric inference which can be highly demanding of capacity, particularly when there is little contextual support for the inference (LeDoux, Blum, & Hirst, 1983).

A review of the relevant literature provides some findings suggestive of the validity of a capacity-decline analysis of age differences. As this analysis predicts, there seems to be little or no age deficit in aspects of word meaning activation which have been identified as automatic in research with young adults. For example, word naming and lexical decision tasks have revealed minimal age differences either in lexical access time (Bowles & Poon, 1985; Cerella & Fozard, 1984; Mueller, Kausler, & Faherty, 1980; Waugh & Barr, 1982) or in semantic priming effects (Cerella & Fozard, 1984; Howard, 1983; Howard, McAndrews, & Lasaga, 1981; but see Madden, 1985).

Not all aspects of the lexical–semantic processing of words show age invariance, however. For example, in addition to investigating age differences on a lexical decision task (and finding none), Bowles and Poon (1985) compared younger and older adults on a task that required them to name the target words corresponding to definitions provided by the experimenter. Bowles and Poon argue that the definition of a word provides only indirect access to the lexical (i.e., phonetic) information needed to name the word, and that age-sensitive retrieval processes are involved in finding that information. If these age-sensitive retrieval processes are capacity demanding (as implied by Bowles and Poon), then the finding in this study of an age deficit on the word retrieval task is consistent with the reduced-capacity view.

A considerable body of research on memory for the content of text is also consistent with the general-capacity view. The age deficits are widespread; they occur whether the text is read or heard, whether the retention test is immediate or delayed, and whether recall or recognition tests are used (Hultsch & Dixon, 1984; Kausler, 1982; Salthouse, 1982). Adults with superior verbal–intellectual ability do seem to demonstrate some protection from aging declines in discourse processing (e.g., Hultsch & Dixon, 1984; Hultsch, Hertzog, & Dixon, 1984). However, given the possibility that high verbal ability subjects have greater capacity or that they use more efficient processing strategies than do those with lower verbal ability (cf. Cohen, this volume), even this last trend may fit a capacity model. Thus, the bulk of the literature on prose processing, from semantic activation to recall, is consistent with a general-capacity view of age deficits.

Our own research began as an attempt to apply the general-capacity framework to the ability to form and remember inferences. The first of two major reasons to focus on inferences is that they are widely believed to be critical to the process of understanding discourse (e.g., Bransford, 1979; Harris, 1981). Indeed, the formation of a coherent and integrated representation of a text typically requires the generation of anaphoric, causal, and other types of inferences to connect the various pieces of explicit information to one another (e.g., Clark, 1977; Garrod & Sanford, 1981). Second, unlike the task of memorizing lists of unrelated items, all adults have had considerable practice at understanding and remembering discourse, possibly making text processing tasks more familiar than others to elderly adults.

Because the encoding of implicit information is considered to involve processing beyond that required for encoding of explicit text information (e.g., Clark, 1977), the general-capacity view predicts a greater age deficit in processing implicit as compared to explicit text information. A number of studies have obtained results consistent with this prediction (Cohen, 1979, 1981; Light & Capps, 1986; Light, Zelinski, & Moore, 1982). However, there are some studies, including those of

Belmore (1981) and Till (1985), that did not find a greater age deficit for implicit than for explicit information.

As noted by Reder, Wible, and Martin (1986), analysis of the inferences used in the various studies suggests a possible resolution of these conflicting results. Specifically, it is likely that across studies, the inferences used varied in their demands on cognitive capacity. In cases where the inferences require only a minimal increment of capacity beyond that required for processing of explicit information, it would not be surprising if the usual finding of a greater age deficit for inferential than for explicit information does not hold. More effortful inferences should, of course, show the expected pattern of age differences.

Consider now the contrast between the materials used by Belmore (1981) and those used by Cohen (1979). To judge from the samples provided, Belmore's inferences were based on obvious connections between text information and basic knowledge about how the world works. For example, one passage required the subjects to infer that a vase located on the dinner table contained the roses that some dinner guests were admiring. For such inferences, limited processing of the texts would have sufficed. By contrast, Cohen's inferences appear to have required the integration of specific, detailed information from within the texts and so to have been more demanding of capacity than were the well-learned, preexisting connections used by Belmore. The conflict between Belmore's and Cohen's results on age differences in inferential processing can then be attributed to the use by Belmore of relatively nondemanding inferences and by Cohen of relatively demanding inferences. The research described next provides some data relevant to this line of argument.

Experiments

A major goal of our experiments on age differences in inference generation is the testing of two predictions of the capacity-decline view: (1) that there is an age deficit in inference generation, and (2) that the age deficit is greater for difficult, capacity-demanding inferences than for easy, relatively noncapacity-demanding inferences. To vary ease of inference generation, we used the following scheme, borrowed from Alba (1981). For each paragraph-length passage, a piece of information, *central* to an understanding of the passage, was designated the *target* fact. For example, in the passage entitled *The Artist*, the central event is a phone call that the artist receives while *busily painting one day*. Essential to a correct understanding of this passage is the encoding of the target fact that the artist was told in the phone call that he had 3 more months to live (rather than to finish the painting he was working on). Three versions of each passage were written in such a way as to vary the difficulty of arriving at the proper interpretation of the target fact.

In the *explicit* version, the target fact is actually presented. In the other two, the target information is implicit and so its encoding requires an inference. In the *expected inference* condition, there is strong contextual support for the target inference from the beginning of the paragraph (e.g., in the first sentence it is stated that the artist was expecting a phone call from his doctor's office). Drawing an inference in this condition should be relatively easy, requiring only the most obvious elaborations of the explicitly presented information. Furthermore, although in a number of cases the correct inference requires the activation of the typically less probable interpretation of a homophone (e.g., *camera* shot rather than *rifle* shot in a passage about a safari), Hess and Higgins (1983; Hess, 1984) have recently demonstrated that older adults, like younger ones, are sensitive to the semantic context in their interpretation of such words.

By contrast to the expected condition, drawing the correct inference in the *unexpected* condition should be considerably more effortful. The potential for increased effort demands derives from the lack of initial contextual support for the target inference (no mention is made about expecting a doctor's call), and from the fact that the initial context misleads the listener into drawing an incorrect inference (the artist is said to be concerned about an exhibit deadline). It is only later in the passage when a piece of information inconsistent with the initial interpretation is presented (the artist's shock at hearing bad news from his doctor is mentioned) that the subjects are led to question their first interpretation of the passage. At this point, the incorrect inference must be suppressed, and memory of the preceding text has to be searched to find the basis for the correct inference and thus for a coherent representation of the passage. Our expectations were that the unexpected condition would be particularly difficult for older adults, and that the age deficits would be greater for the unexpected than for the expected condition.

Across experiments, we have used both oral and self-paced visual presentation procedures. The differences between these procedures enable a test of the capacity decline view. Specifically, a self-paced procedure allows subjects to vary their reading rate in response to high processing demands. If older subjects do slow down when demands increase (e.g., when an inference is required), the result (in comparison with oral presentation) could be a smaller age deficit in inference generation, especially for easy inferences. (For a similar line of reasoning and for confirming data, see Cohen, 1981.) Furthermore, the self-paced condition allows for the collection of reading times. Our assumption, shared with many in this research domain (e.g., O'Brien & Myers, 1985), is that reading time measures offer a window into underlying cognitive processes, and so should add to our understanding of the impact of reduced capacity on inference generation.

Methods

What follows is a detailed description of an experiment that used a self-paced presentation procedure in which subjects read experimental passages displayed one sentence at a time on a video monitor. Reference will also be made to the results of an experiment (Zacks, Hasher, Doren, Hamm, & Attig, 1987) in which the same materials were read to the subjects at a normal reading rate. The materials used in these experiments consisted of explicit, expected, and unexpected versions of each of 12 passages. Each passage described a concrete scene or event (e.g., a father and son preparing dinner, an individual waiting for a ride home from work). In developing the materials, we tried to use content that would be equally familiar to the

Table 9.1. *Example of the materials used in the research*

The artist

Explicit and expected versions (in the latter, the phrase in parentheses is omitted)

The artist was busily painting one day when he received the phone call he had been expecting from his doctor's office.
He was concerned about the results of a series of lab tests he had taken.
The artist was told he had three more months (to live).[a]
He was shocked to hear this kind of news from his doctor.[b]
Although he had not been feeling well, he still had not expected to hear such bad news.[c]
His doctor expressed sympathy and hung up.
Suddenly, the painting was no longer important.
The artist mixed himself a stiff drink.

Unexpected version

The artist was concerned about having his painting ready for the exhibit deadline.
While he was busily painting one day, he received a phone call.
The artist was told he had three more months.[a]
He was shocked to hear this kind of news from his doctor.[b]
Although he had not been feeling well, he still had not expected to hear such bad news.[c]
His doctor expressed sympathy and hung up.
Suddenly, the painting was no longer important.
The artist mixed himself a stiff drink.

Control questions

What was the artist doing when the phone call came?
What did the artist do after he got off the phone?

Question on the target fact

The artist was told he had three more months to do what?

[a] The sentence in which the target inference should occur in the expected condition.
[b] The critical sentence in the unexpected condition and the comparison sentence in the other two conditions.
[c] The postcritical sentence.

older and younger subjects. Data from a pilot study suggest that we were successful in achieving this goal. When allowed to consult a printed version of the passages, neither age group displayed significant problems with answering comprehension questions about the passages. In addition to the passages, the experimental materials included direct questions (e.g., *The artist was told he had three more months to do what?*) which were used to test retention for both target and control information. The latter was relatively unimportant information which was explicitly stated in all three versions of the passage. A complete example of one set of the materials is presented in Table 9.1.

It should probably be acknowledged that we designated the target facts as central information and the control facts as peripheral information, not on the basis of a formal analysis of passage structure such as that of Kintsch (1974), but on more intuitive grounds. Nonetheless, our intuitions are supported by data from a pilot study in which (young adult) subjects read and produced written recalls of the passages. According to the importance level research, if we were correct in assuming that the target information was more important than the control information for each passage, then the probability of recalling the target information should correspondingly be greater than the probability of recalling the control information. This indeed is what we found. For example, for the explicit versions, the mean percentages recalled were 82% and 45%, respectively. Additionally, it can be noted that although age differences in importance level effects were not a central concern of our research, the fact that the target and control information for each paragraph differed in importance level allows our data to address this issue.

Every subject read a single version of each of the 12 passages, with four each from the expected, unexpected, and explicit conditions. Across subjects, an equal number processed each of the passages in each of the three versions. This meant that the *same* target information was tested in the explicit condition and in the two implicit conditions, and that comparisons between explicit and inferential information and between easy and hard inferential information were not complicated by differences in other variables such as importance level.

Each passage was presented one sentence at a time at a rate controlled by the subject who pressed a button whenever he or she was ready for the next sentence. Each button press resulted in the erasure of the current sentence and the presentation of the next one. The subjects read the first six passages and then were tested with the target and control questions on those; then the same procedure was followed for the remaining six passages. On the retention test, the questions appeared on the video screen but were answered orally by the subjects.

Thirty subjects from each of two age groups (means = 19.7 and 72.3 years) participated in the study. The young subjects were university undergraduates who participated for course credit. The older adults were community residents, who were in reasonably good health for their age and who were paid for their participation. The younger subjects were mostly freshmen and sophomores; the older subjects had a mean of 14.2 years of education. In addition, all subjects were administered the vocabulary subtest of the Wechsler Adult Intelligence Scale – Revised (WAIS-R). The mean standardized scores on this instrument were 11.23 for the younger adults and 12.27 for the older ones.

Results and discussion

We first describe the results for the recall data and then the reading time results. Table 9.2 presents the percentage correct recall of the control and target information as a function of passage version and age. From the table it is clear that an importance level effect was obtained for both age groups and that it was approximately equal in magnitude across ages: The average target–control difference was 16.2% for the younger subjects and 19.3% for the older ones.

Because the target and control questions tested different information, we examined age and version differences for each type of question separately. In the separate analysis of the control information recall, the only significant effect was that for age, with the age deficit being 12.8%. By contrast, the analysis of the data on target information recall revealed significant main effects of both age and passage version and a

Table 9.2. *Percentage recall of control and target information*

	Control information		Target inferences	
Passage	Younger	Older	Younger	Older
Explicit	74.6%	63.8%	98.3%	90.0%
Expected	78.8%	65.8%	92.5%	92.5%
Unexpected	78.8%	64.2%	90.0%	69.2%
Mean	77.4%	64.6%	93.6%	83.9%

significant Age × Version interaction. For both age groups, the lowest level of recall of the target information occurred in the unexpected condition. (For the younger subjects, only the explicit–unexpected difference was significant; for the older ones, the unexpected condition differed significantly from the other two.) However, the striking aspect of the target recall data is the poor performance of the older subjects on the unexpected inferences relative to their performance in the other two inference conditions. The age deficit in the unexpected condition was 20.8% as contrasted to 8.3% in the explicit and 0% in the expected condition. (Although relatively small, the age difference for the explicit condition was nonetheless significant.)

The target recall results can be related to the existing literature on age difference in inference generation and to the reduced-capacity views of aging. With regard to the former, the results replicate in a single experiment both the finding of no age difference in inference generation (the expected condition; cf. Belmore, 1981) and the finding of a significant age deficit (the unexpected condition; cf. Cohen, 1979). Our earlier suggestion that inference difficulty was a likely source of the conflicts in the literature is therefore supported.

As to the relevance of these findings to reduced-capacity models, one prediction of such views was clearly confirmed. Specifically, the age deficit was largest in the most demanding condition – the unexpected inference condition. However, another fairly direct prediction of the reduced-capacity view, that the age deficit in the expected condition should be intermediate between the other two conditions, was not supported.

This apparent disconfirmation of the capacity view should probably be evaluated in the light of other data from our research program which suggests that the disconfirming outcome is tied to the self-paced presentation mode of the current experiment. That is, because they could slow down their reading rate, the older adults were apparently able to compensate somewhat for their reduced capacity. At the least, they could compensate sufficiently to handle, without deficit, the relatively small increases in capacity needed for the generation of Expected inferences.

A different pattern of target recall was obtained in another experiment that utilized the same materials and same general design but an oral presentation procedure (Zacks et al., 1987). These data, along with the target recall data of the self-paced reading study, are shown in Figure 9.1. It can be seen in the figure that the overall

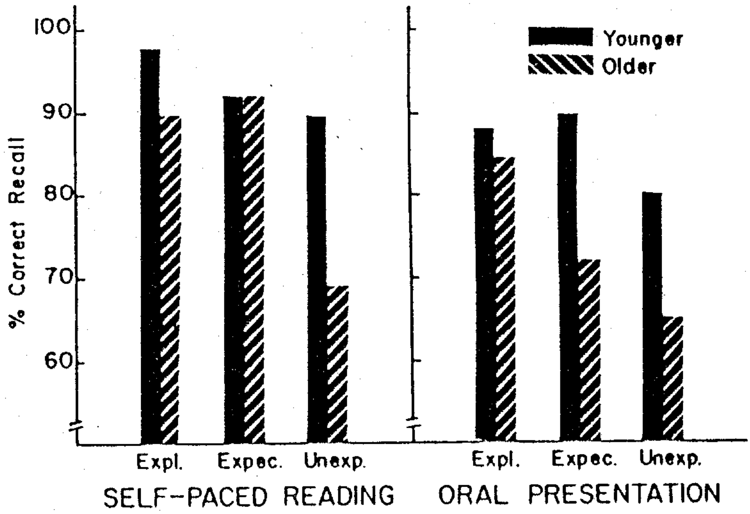

Figure 9.1. Percentage correct recalls of the target information in the self-paced reading and oral presentation studies. (Adapted in part from Zacks et al., 1987, by permission of *The Journal of Gerontology*, vol. 42, no. 4, 1987.)

performance level was lower in the oral presentation experiment than in the self-paced reading experiment. However, more important is the fact that in contrast to the reading situation, the oral presentation mode resulted in a significant age deficit for both the expected and the unexpected inferences. Apparently, when they are not allowed to control the rate of information input, the older subjects are not able to handle as efficiently as younger subjects the processing demands of either easy or difficult inferences (cf. Cohen, 1981). Another important point highlighted by this comparison of the target recall results of the two experiments is that the processing demands of a particular text variable cannot be established in isolation from a consideration of the presentation mode and its influence on momentary demands on processing capacity.

We turn now to the reading time data of the self-paced study. We will focus in particular on aspects of these data that might provide further insight into the large age deficit in encoding of unexpected inferences. Because sentences varied in length, reading times were computed per word. Consistent with the widely observed slowing of mental processing in older adults (e.g., Salthouse, 1982), the older adults paced themselves more slowly (mean reading time per word = 502 msec) through the passages than did the younger adults (mean = 340 msec).

Three sentences were singled out for specific analysis of their reading times. (These sentences are marked in the example in Table 9.1.) The first of these was the sentence that explicitly stated the target information in the explicit condition and that invited the target inference in the expected condition. The analysis of this sentence was relatively uninformative, with no effects of passage version being

Table 9.3. *Reading speed (in msec/word) for inference, critical, and postcritical sentences*

	Explicit	Expected	Unexpected
Younger subjects			
Inference	318	350	323
Critical	347	347	396
Postcritical	284	299	325
Older subjects			
Inference	469	495	506
Critical	514	496	577
Postcritical	423	437	476

found for either age group. This was probably due to the relative insensitivity of whole-sentence reading times to small increments in processing demands such as would be produced by the easy, expected inferences.

Much more intriguing was the pattern of data for the sentence in which the target inference is first clued in the unexpected passage versions. It is here that subjects reading an unexpected passage first receive information that is incongruent with their initial interpretation of the passage. For example, in the unexpected version of the artist passage, subjects assume that the artist is concerned about the exhibit deadline until they read "He was shocked to hear this kind of news from his doctor." Subjects in the explicit and expected versions read the identical sentence, but these subjects already know that the artist was worried about his doctor's report. No differences are expected between these two conditions. However, in the unexpected condition, reading speed for this sentence, called "critical" in Tables 9.1 and 9.3, should be considerably slower. And indeed, this pattern prevails (see Table 9.3) with a reliable difference among versions that is entirely due to the slower reading of the critical sentence in the unexpected version. Reading times for this sentence in the explicit and expected versions did not differ from each other, and as with all the reading time results, the older subjects read this sentence more slowly than the younger subjects.

We also expected, but did not find, a significant Age × Version interaction, with the older subjects showing less of an effect of passage version than the younger ones. Our reasoning here was as follows: The slowdown in reading time for the critical sentence in the unexpected condition reflects the extra processing needed to generate the target inferences in this condition. Because older subjects are less likely than younger ones to generate these inferences (and the recall data support this supposition), they should show less of a slowdown than the younger subjects. But they do not: There was not even the slightest hint of the predicted interaction.

In order to explore this issue further, we looked at the reading times for the sentence immediately following the critical sentence. We were led to this analysis by a suggestion of Mary Attig's as well as by some recent work of O'Brien and Myers (1985). In research with young adults, O'Brien and Myers obtained data suggesting that an unanticipated word in the midst of a passage leads to reprocessing of the text preceding the surprise. This covert reprocessing occurs during the reading of the remainder of the passage, reducing reading speed and resulting in superior memory for early portions of passages containing unpredicted words. Although we have no appropriate measure of passage recall to compare to O'Brien and Myers's, the reading times for the postcritical sentence are relevant to this type of theoretical argument.

In analyzing the reading times for the postcritical sentence (also shown in Table 9.3), we expected to see a "spillover" slowdown from the preceding sentence in the unexpected condition. The slowdown would reflect a continuation of the reprocessing of the text that was initiated by the critical sentence. Because our original concept was that the older subjects would be limited in the amount of reprocessing they could carry out, we expected them to show a smaller spillover effect than the younger adults. The analysis of the postcritical sentence reading times revealed (unsurprisingly) that the older adults read this sentence more slowly than the younger adults; additionally, the effect of passage version was as predicted, with the slowest times in the unexpected condition. However, once more our expectations about age differences were disconfirmed: The spillover effect in the unexpected condition was of approximately the *same* magnitude for younger and older adults (interaction $F < 1$).

The data from this experiment make it clear that both younger and older adults realize that the critical sentence in the unexpected version requires special processing, resulting in slower reading rates. This slowdown also spills over to the succeeding sentence. Because these effects on reading time are similar for both age groups, the reading time data do not clearly point to a specific locus of deficit that would account for the older adults' depressed recall of the target inferences in the Unexpected condition. However, a number of possibilities can be suggested. One is that despite the slowdown in reading time, the older subjects are still less likely than the young to draw the appropriate inference, perhaps because they are unable to retrieve enough of the preceding text to do so (cf. Glanzer, Fischer, & Dorfman, 1984; Glanzer & Nolan, 1986). Another possibility is that having drawn the correct inference, the older subjects fail to completely reinterpret the passage as a whole and therefore they fail to integrate the inference into a coherent text representation.

In general, our working assumption is that the difficulty of the unexpected passages stems from the need to juggle making of the inference with the task of reinterpretion and integration of the text as a whole. We assume that the young are more successful at handling these two tasks than the elderly, leaving the former with access to a variety of cues that can help them to answer the inference probe question. The older adults' reduced probability of answering the target question may stem in part from a lowered probability of generating the critical inference during comprehension. However, they may also have problems even when they succeed in generating the critical inference. In this case, the failure to encode a well-integrated representation of the text may have left them with fewer cues with which to access the target information on the recall test.

Such an explanation of the inference recall results is broadly consistent with the general capacity view with which we began. Certainly, it is compatible with this view to argue that the reduced capacity of the elderly decreases their ability to retain new information while reconsidering earlier information. However, although this argument is compatible with the general-capacity model, it is not specifically derived from it. Our current view is that an unelaborated capacity view lacks the analytic power to provide a detailed specification of the nature of age differences in processes such as inference generation and text reinterpretation. Because of this, we were motivated to develop a more analytic model, one that can be readily tied to specific models of text processing. In the final portion of this chapter, we outline this model.

Capacity theory revisited: The elaborated model

Our revised capacity model represents an attempt to mesh general-capacity theory with current conceptualizations of discourse processing mechanisms, especially those involved in inference generation. The model ties the notion of capacity to that of working memory (e.g., Anderson, 1983; Baddeley, 1981; Baddeley & Hitch, 1974; Daneman & Carpenter, 1980, 1983; Klapp, Marshburn, & Lester, 1983).[1] Working memory (as distinguished from short-term memory; see Klapp et al., 1983) is assumed to have *both* storage and processing functions which trade off for capacity (e.g., Baddeley & Hitch, 1974; Daneman & Carpenter, 1980, 1983). Beyond this basic idea, the functions and operating mechanisms of working memory have as yet to be clearly defined. In fact, it is likely that the way that this system functions is highly task specific (Richardson, 1984). If so, hypotheses about age changes in working memory must be tied to a model of the experimental tasks.

We assume that in the case of text processing, two types of information are served by the storage function of working memory: (1) information derived from preceding text; and (2) prior knowledge activated from long-term memory. The more of both types of information that can be stored in working memory, the deeper will be the understanding of subsequent text (e.g., Daneman & Carpenter, 1980). The recent research of Glanzer et al. (1984; see also Glanzer & Nolan, 1986) provides striking evidence that the efficient operation of comprehension mechanisms is dependent on having prior text information (especially the last sentence or two) available in working memory.

The processing function of working memory encompasses a variety of processes that occur during text encoding. Some operate at the level of individual words and phrases and are closely tied to the words that are currently being processed. Included here are lexical access, sentence parsing, and derivation of propositions. These "within-proposition" processes are not heavily dependent on the storage functions of working memory. Contrasted with these are "between-proposition"[2] or higher-level activities such as the integration of new with prior information, the formation of inferences, and the derivation of summary propositions. These latter functions all require that the relevant information be available in the storage component of working memory. (This particular view of text processing builds upon such hierarchical models as those of LaBerge & Samuels, 1974, and of Graesser, Hoffman, & Clark, 1980).

The aging assumptions of our revised capacity model are (1) that aging is associated with an overall decline in working-memory capacity, and (2) that this capacity decline is unevenly distributed among the various storage and processing components of working memory. In particular, the major direct impact of aging will be found in a reduced storage capacity in working memory. In turn, the reduced storage capacity will impact most heavily on between-proposition processing, because between-proposition processes such as inference generation require that critical information be available in working memory (cf. Glanzer et al., 1984). By contrast to the direct effects of aging on buffer storage and to the indirect effects on between-proposition processing, we assume that the capacity allocated to within-proposition or ongoing processing is maintained at a level similar to that in young people. (See Light and Anderson, 1983, for another argument that older individuals give high priority to on-line discourse processing at the expense of other encoding processes.) The rationale for assuming this particular allocation of capacity decline is three fold: (1) The initial stages of within-proposition processing (e.g., lexical access) tend to be stimulus driven and automatic. (2) Social convention and other pragmatic considerations demand of a person supposedly conversing, reading, or listening that he or she will at least decode individual words and phrases. This means that even when within-proposition encoding puts relatively high demands on processing capacity, older adults will put a high priority on this type of encoding. (3) Finally, a number of recent empirical findings suggest that variables influencing demand on the buffer have a special impact on the elderly. For example, Light and Capps (1986) have shown that the age deficit in the ability to determine the referent of a pronoun increases with an increase in the time span over which the antecedent information must be held in working memory (see also Cohen & Faulkner, 1984; Wright, 1981).

Although the research described in this chapter does not provide a definitive test of the elaborated model, its results are readily interpreted in terms of the model. For example, the presumed reduction in older adults' buffer storage capacity provides an explanation of their depressed recall of the unexpected target inferences in the self-paced reading study: In comparison to younger subjects, older adults have available in working memory less of the information that is needed for generating the correct inference and for integrating it into a revised text representation. Furthermore, because the constraints on buffer capacity determine both the "window" of preceding text that can be maintained in working memory and the amount of text information that at any one time can be reactivated from the long-term store, older subjects may be at a disadvantage even when (as in this study) they can control the rate of information flow: The slowed reading is unable to compensate completely for their inability to hold enough relevant information in working memory simultaneously.

Obviously, considerable research will need to be done to establish the value of the elaborated capacity model and the validity of speculations such as those of the preceding paragraph (but see also Light and Albertson, this volume). However, we believe that our adoption of a working-memory analysis and our assumptions regarding the allocation of capacity declines associated with aging add considerable power to the general-capacity view, a view that has had at least moderate success in accounting for standard memory findings in cognitive gerontology (cf. the earlier discussion of Craik's capacity theory). It is our working hypothesis that such an analysis will enable us to specify exactly where inference generation in older adults breaks down and so ultimately help us to determine how it might be repaired.

Notes

1 We acknowledge that most discussions of working memory distinguish between a phonemic response buffer (or articulatory loop) and a central executive processor (e.g., Baddeley, 1981; Baddeley & Hitch, 1974; Richardson, 1984). The phonemic response buffer seems to have limited functions; it serves as a source of supplementary storage capacity in tasks (e.g., memory span) that formally require the maintenance of accurate serial-order information (Richardson, 1984). Because we are not interested in such tasks, we ignore the phonemic response buffer in what follows and treat the term "working memory" as a synonym for the central executive processor.

2 It is of course only roughly true that within-proposition processing places less demand on storage capacity than does between-proposition processing. For example, the encoding of certain multi-argument propositions can place relatively high demands on storage capacity in working memory. Nonetheless, we think it useful to distinguish between aspects of encoding that typically place a relatively high load on storage capacity and those that do not. Furthermore, it should be noted that we believe that the factors that influence storage demands are somewhat independent of those that influence ongoing processing demands. Because of our assumptions about the preservation of ongoing processing activities in the face of reduced capacity, age differences should be more sensitive to the former than to the latter.

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