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Encoding and Memory of Explicit and Implicit Information

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The usefulness of a general capacity model for predicting age differences in memory for critical information in text was assessed. Passages that either explicitly stated or implied, in either a predictable or unpredictable manner, a fact central to understanding were read to study participants. No age differences were obtained in the recall of explicit central facts, but the younger adults outperformed the older adults when these facts had to be inferred. A revised capacity model, which implicates encoding processes in the breakdown of inference formation, is outlined to account for these and other data.

THE experiment reported here concerns adult age differences in the processing of inferences in text. We approached this problem from a limited capacity model of cognitive functioning (e.g., Kahneman, 1973). Such models share two basic assumptions: (a) Information processing is constrained by the amount of mental resources available at a given moment and (b) cognitive activities vary in the mental resources they require for maximal performance. With respect to aging, a third assumption is added: Mental resources decline during the later years (e.g., Craik, 1983; Hasher & Zacks, 1979). Together, these assumptions yield the general prediction that age deficits in performance will be increasingly severe the more demanding of capacity a particular cognitive activity is.

This view has been applied to recent studies of adult age differences in text processing (e.g., Cohen, in press; Zacks & Hasher, in press). This particular application of the limited-capacity view is facilitated by current theories of text processing (e.g., Haberlandt & Graesser, 1985), which suggest that the mental activities involved in discourse comprehension and memory vary in their demands on capacity. In particular, compared to the encoding of explicit information, the encoding of inferences is thought to place extra demands on capacity (e.g., Garrod & Sanford, 1981). Thus, two theoretical lines converge to predict that aging declines generally will be greater for the encoding of implicit as compared to explicit information. This issue is important because inference generation is central to the adequate comprehension of discourse.

Recent research on age differences in inference generation shows inconsistent findings. Some studies report larger age deficits in the processing of implicit as compared to explicit information (Cohen, 1979, 1981; Light et al., 1982). Other studies find no evidence that older adults have particular difficulty with inferential information (Belmore, 1981; Burke & Yee, 1984). These conflicting findings may stem from differences across studies in the capacity demands of particular inferences. Although the generation of many inferences may require a significant increase in capacity expenditure beyond that required for encoding the same information when it is explicit, some inferences may involve only minimal increments in capacity expenditure. If so, it is possible (Reder et al., 1986; Zacks & Hasher, in press) that the studies that obtained greater age deficits for inferential than for explicit information used relatively hard inferences, whereas those that did not used relatively easy ones.

The validity of such an argument is assessed directly in the present experiment. By comparing the generation of easy and hard inferences to the processing of the same information when it is explicit, the present experiment provides a strong test of the capacity theory prediction that the greater the resource demands of a target mental process, the greater should be the impact of age-associated declines in available capacity.

A secondary issue addressed here is the contribution of verbal ability to age differences in inference generation. Some researchers have suggested that age differences are reduced for individuals of high verbal ability (Rice & Meyer, 1986; Till, 1985; see Dixon et al., 1984). However, the relevant findings are quite mixed (Dixon et al., 1984), and it is unclear from a theoretical perspective what such an interaction means. One possibility is that verbal ability contributes to text processing skill independently of age and other individual difference factors (Baddeley et al., 1985). Alternatively, one can argue in the context of a capacity view that greater verbal ability is associated with greater capacity, at least for verbal tasks. For example, this might be the result of higher verbal skill enabling more efficient performance of low-level skills (e.g., lexical access), thus allowing more spare capacity to be allocated to other skills, such as integrating information across portions of a text (Hunt, 1985; Just & Carpenter, 1987). If so, the impact of differences in verbal ability should parallel the impact of age differences. Thus, in the present experiment, low verbal individuals should show a deficit in inference generation, and that deficit should increase with increasing inference difficulty.

METHODS

Materials and design. — The ease of generating an inference while reading a paragraph was varied using the following scheme: Each paragraph-length passage had a *target* fact central to its understanding. For example, in a passage describing a safari, the central action concerned a shot taken with a camera (rather than a gun). Three versions of each passage were written in order to vary the difficulty of arriving at the proper interpretation of the target fact. In the explicit version, the target fact actually was presented. In the other two, the target information was implicit, and so its encoding required an inference. In the expected version, there was strong contextual support for the target inference from the beginning of the paragraph. (In the first sentence, the trip was called a photographic safari.) In this version, drawing an inference required minimal elaboration of the information actually presented and should have been relatively easy. Conversely, drawing the correct inference in the unexpected condition should have taken considerable effort because the initial context provided little support for the target inference (the trip was simply called a safari) and tended to mislead the listener or reader. (Most safaris are organized to shoot game, not photograph them.) It was expected that, if individuals were to draw an incorrect inference (that a gun was being shot), their initial inference would have to be abandoned when conflicting information was presented (when a picture was mentioned). They also would have had to search their memory of the preceding text in order to find a basis for the correct inference and, therefore, for a coherent representation of the text. This extra processing seemed especially demanding of capacity.

The experiment comprised a 2 (ages) × 2 (verbal ability) × 3 (inference condition) mixed factorial design, with the inference conditions tested within individuals. The experimental materials consisted of three different versions of 12 passages, each of which described a concrete scene or event (e.g., a father and a son preparing dinner). Participants heard four passages from each of three conditions: explicit, expected, and unexpected versions. Passage version was counterbalanced across participants so that the three forms of a passage were presented to equal numbers of individuals at each age level. Thus, across participants, performance in the explicit, expected, and unexpected conditions was evaluated over the *same* target facts.

Three direct questions for each passage were used to test memory for both the target information and for control facts. Because the target questions addressed central information in the passages, an error in answering one of these questions indicated a serious misunderstanding of the relevant passage. By contrast, the control questions (two for each passage) concerned relatively unimportant details stated explicitly in all three versions of a passage. For the safari passage, the target question was, "The hunter took a shot with what?", and one of the two control questions was, "What was the weather like when the hunter found the lion?"

The materials were presented both to younger and older adults in order to pretest for content familiarity and to verify that the target inference could be derived from both the expected and unexpected versions by the end of a passage. Several rounds of pretesting were necessary before we arrived at acceptable passages. For the final set of passages, 20 older adults (*M* age = 68.6 yrs.; range = 60 to 78 years) read, at their own rate, six expected and six unexpected passages; no explicit passages were included in this pretest. Each text was presented on two successive pages. The first page contained the text up to the last point at which, in the unexpected version, the original interpretation could be maintained; the next sentence contained the initial indication that the original interpretation was incorrect. After reading the first part of the text, the participant answered the target inference question for that passage. Then he or she turned to the second page, which contained the entire text. After reading the second page, the participant again answered the target inference question. During both question answering attempts, the written text (part or whole) was available to the participants, who were encouraged to refer to it as necessary.

At the first questioning point, participants provided the target information (i.e., the final, correct answer) 75% of the time for expected passages and 18% of the time for unexpected passages. Responses for the unexpected passages indicated that the competing inference (e.g., for the safari passage, that the shot was taken with a gun) had been derived. After reading the entire passage, however, the participants responded overwhelmingly with the target inferences — 95% and 90% for the expected and unexpected conditions, respectively. These results indicate that older adults can adequately comprehend the texts. There was no evidence of any problems with a lack of content familiarity. (The small error rate of the older adults in the second testing of the target question will not be a source of concern in cross-age comparisons because pretests of the materials with younger adults also produced an error rate of approximately 5%.)

Procedure. — Participants were tested individually. The instructions stressed the importance of listening carefully to each of a series of short stories because questions would later be asked about them. The experimenter read each passage beginning with its title at a loudness level determined to be suitable for each individual based on an initial informal conversation. A normal oral reading rate was used. Questions were asked after sets of six passages, with passages tested in their order of presentation, which varied randomly across participants.

The vocabulary subtest of the Wechsler Adult Intelligence Scale (WAIS-R) was administered prior to the presentation of the first set of six passages, along with a questionnaire asking participants about their educational and work histories and their general health. A 15-min break between the two sets of six paragraphs was filled with the administration of two other standard tests, the WAIS-R digit span subtest and a self-administered checklist of psychological symptoms.

Participants. — Forty-eight young college students (*M* age = 20.4 years; range = 18 to 35 years), most of whom were in their first two years of study, were tested, as were 48 older adults (*M* age = 73.2 years; range = 64 to 90 years). The latter group was comprised of community residents, recruited from a variety of senior citizen organizations, who were paid for their participation. According to self-reports, they were active in the community and in relatively good health. They reported having an average of 13.4 years of education.

RESULTS

Verbal ability differences. — The mean raw scores on the WAIS-R vocabulary test were 48.3 and 49.2 for the younger and older adults (*SD* = 10.24 and 12.40, respectively). Within each age group, individuals who scored at the median or higher were placed in the high verbal subgroup; those who scored below the median were placed in the low verbal subgroup. For both older and younger adults, there were 25 individuals in the high ability subgroup and 23 in the low ability subgroup. The mean vocabulary scores of the high and low ability subgroups were 56.0 and 39.9, respectively, for the younger adults and 58.8 and 38.8, respectively, for the older adults.

The impact of verbal ability on performance on control and target questions can be seen in Table 1. Higher verbal ability was associated with better performance on both types of questions and for both younger and older adults. These observations were confirmed in separate 2 (verbal ability) × 2 (age) × 3 (passage version) analyses of the answers to the control and target information questions. The high verbal group significantly outperformed the low verbal group on both the control, $F(1, 92) = 15.85$, $MSe = .0548$, and the target questions, $F(1, 92) = 10.31$, $MSe = .0695$. (A critical value of $p < .05$ is used throughout this paper). Although an apparent interaction between age and verbal ability is present for both target and control information, it reached significance only for the control information, $F(1, 92) = 4.72$, $MSe = .0548$. This interaction reflects the fact that, for younger adults, verbal ability has only a small impact on performance, with only a 5% difference in recall between high and low ability groups. For older adults, verbal ability has a far larger impact — a 17% difference. Thus, differences in verbal ability may play a larger role in prose processing for older adults than for younger adults (see Rice & Meyer, 1986). Verbal ability also may modulate the effects of passage version, as is discussed below.

Table 1. Percent Correct Recalls of Control and Target Information as a Function of Age, Verbal Ability, and Passage Version

Vocabulary Score	Younger adults High	Younger adults Low	Younger adults *M*	Older adults High	Older adults Low	Older adults *M*
Control information						
Passage version						
Explicit	82.0	71.2	76.8	67.0	48.4	58.1
Expected	84.0	76.6	80.5	67.0	50.5	59.1
Unexpected	68.0	71.2	69.5	67.0	51.1	59.4
M	78.0	73.0	75.6	67.0	50.0	58.8
Target information						
Passage version						
Explicit	92.0	83.7	88.0	91.0	79.4	85.4
Expected	94.0	85.9	90.1	82.0	62.0	72.4
Unexpected	82.0	79.4	80.7	70.0	60.9	65.6
M	89.3	83.0	86.3	81.0	67.4	74.5

Age differences in recall of control information. — Younger adults were better at recalling control details than the older adults for all passage versions, $F(1, 92) = 37.90$, $MSe = .0548$. In addition, there was a significant age × passage version interaction, $F(2, 184) = 3.66$, $MSe = .0275$, reflecting an effect of passage version for the younger participants only. Specifically, for the younger, but not for the older adults, recall of control information was depressed in the unexpected condition (Newman-Keuls tests). Subsequent analyses indicated that the reduced performance in the unexpected condition was confined to high verbal young adults. This result may or may not be spurious; in another study, using the same materials but different procedures, we did not find this effect (Zacks & Hasher, in press). In sum, with the exception of young high vocabulary participants reading unexpected passages, there was an overall age deficit across passage types and ability levels in the recall of control details.

Age differences in recall of target information. — The analysis of the target recall data showed a significant effect of age, $F(1, 92) = 14.47$, $MSe = .0695$; passage version, $F(2, 184) = 15.28$, $MSe = .0287$; and their interaction, $F(2, 184) = 5.55$ $MSe = .0287$. This critical interaction reflects the fact that age differences were restricted to the inferential versions; an age deficit was not detected for explicit passages.

Analyses of target recall performed separately for each age group revealed that passage version influenced target recall for both younger, $F(2, 92) = 4.37$, $MSe = .0266$, and older adults, $F(2, 92) = 15.77$, $MSe = .0308$. However, passage version had different effects for the two age groups (Newman-Keuls tests). For younger adults, performance was equivalent in the explicit and expected versions and was poorer in the unexpected version. For older adults, performance was best in the explicit condition and dropped off an equivalent amount when either easy or hard inferences were required. We had anticipated a continuous decline in performance across the explicit, expected, and unexpected conditions for older adults. And indeed, this pattern is present in the performance of the high verbal older adults. Separate Newman-Keuls tests on the performance of the high and low verbal older adults confirm these observations. Of course, because these are extremely liberal statistical procedures, we do not overemphasize their significance. They do suggest, however, that further comparisons of the inferential abilities of high and low verbal ability older adults are warranted (cf. Till, 1985).

The older participants in this study spanned a large age range, 64 to 90 years, and two additional sets of analyses were performed to determine if the results were uniform across this age range. The first involved analyses of variance (ANOVAs) comparing the performance of those older than 75 ($n = 12$) to the performance of those aged 75 and younger ($n = 36$). No significant effects involving age were obtained for either control or target recall. Correlational analysis also demonstrated that the patterns of performance were fairly constant across this age range. The correlation between age and control recall was small but significant, $r(46) = .264$; that for target recall was not, $r(46) = .113$. Contrast these correlations with those between recall and WAIS-R vocabulary score for these same participants; $r(46) = .591$ and .589 for control and target recall, respectively. In the young adults, the recall-vocabulary correlations were reduced but reliable. Thus, these analyses provide additional support for the importance of verbal ability in inference generation and detail encoding.

Discussion

With few exceptions, younger age and higher verbal ability were associated with better recall of both control and target information than were older age and lower verbal ability. The exceptions are the result of an interesting pattern of interactions among age, verbal ability, and passage version.

The age difference in recall of detailed (or control) information was consistent across passage versions. A capacity model would argue that, in comparison to younger adults, older adults have fewer resources for the kind of elaborative activities required for good recall of minor details.

The pattern of age differences in the recall of information central to an understanding of a passage varied as a function of the demands that a particular passage version made: (a) No age deficits were found when the target information was explicitly stated; (b) age deficits were found when the identical information had to be inferred, whether the inference was easy or hard to make. The age deficit in target recall is best interpreted in terms of effects that occurred primarily at *encoding* rather than during either long-term storage or at retrieval because of the absence of age differences in the explicit condition. The alternative view, that inferences were drawn but forgotten at different rates across ages, requires a theory of storage or retrieval processes that explains how age can have a differential impact when the same information is generated internally as compared to when it is supplied externally.

A capacity interpretation of the inference encoding findings suggests that the available resources of young adults (of both ability groups) are taxed only by difficult inferences. In contrast, the resources of older adults are taxed both by easy and hard inferences.

This account of the results is plausible, but it may be incomplete. The present results can be compared with those of another study (Zacks & Hasher, in press) using the same materials, but with a self-paced presentation method instead of the present experimenter-paced procedure. A different pattern of results was obtained: Specifically, a substantial age deficit was present only for the unexpected inferences, with no deficit for the expected inferences.

Other results suggest similarly that older adults have less difficulty with inference generation when the presentation mode is written and, typically, self-paced (see Belmore, 1981) than when it is oral and, consequently, experimenter-paced, (see Cohen, 1979, experiment 1). (Available data do not allow for a separate analysis of the effects of presentation modality and type of pacing.) Thus, circumstances in which older adults cannot control the rate at which information is presented to them, and in which they are unable to review recently presented material, pose particular problems for them. Such circumstances were present in the current study. They also occur when a speaker addresses a large audience (or an invisible one, as on a video or audio tape), or when a speaker is insensitive to nonverbal feedback.

It appears, then, that momentary demands on capacity are determined by properties of the presentation conditions as well as by the stimulus materials (cf. Stine et al., 1986). To account for such factors, we have proposed (Zacks & Hasher, in press) an elaborated limited-capacity view that incorporates Baddeley and Hitch's (1974) concept of a working memory that has both processing and temporary (i.e., buffer) storage functions. This revised view promises to provide a more detailed account of age differences in prose comprehension than the original. It also has the potential of tying the developmental work to current models of individual differences in reading skill, in particular, to those models which assume that working memory capacity is a determiner of reading skill (Baddeley et al., 1985; Daneman & Carpenter, 1983; Hunt, 1985; Just & Carpenter, 1987).

In our working memory account of age differences, we assume (as did Light & Anderson, 1983) that there is an age-related decline in working memory capacity. We believe that this decline has a greater impact on the buffer storage function of working memory than on the ability to process new material. Factors that might produce this effect include the largely automatic nature of the initial stages of sentence processing and the need to continue processing new material, if one is to keep up with a speaker or to maintain a steady reading rate (Hunt, 1985).

A decline in the amount of information held in working memory can account for the difficulty older adults have with unexpected inferences. Generating these requires the listener to have available information from both the passage (e.g., to check that a gun had not been mentioned explicitly) and general knowledge (e.g., that the mention of a picture implies the use of a camera). Especially in individuals with reduced capacity, this load easily could exceed the amount that can be held in working memory. By contrast, because easy inferences require that less information (e.g., only general knowledge) be available in working memory, the impact of reduced capacity should be lessened. Self-pacing of presentation, as contrasted with experimenter pacing, should also decrease the impact of aging losses in capacity. This is because self-pacing allows for compensatory behavior on the part of those with reduced working memory capacity (cf. Hartley, 1986): For example, Zacks and Hasher's (in press) results with a self-paced presentation mode suggest that, by slowing their rate of processing of new material, older adults are able to reduce the momentary processing load on working memory and, thereby, increase somewhat the capacity available for storage. Consequently, their ability to encode easy inferences is increased. Thus, although speculative, a working memory capacity view has the possibility of accounting for complex interactions among age, stimulus materials, and presentation conditions.

The present study also adds to the growing body of findings (Baddeley et al., 1985; Palmer et al., 1985; Rice & Meyer, 1986) that a vocabulary measure of verbal ability is a strong predictor of text processing skill at all adult ages. In our study, significant differences in favor of the high verbal subgroups were obtained for both younger and older adults and for both control and target information. In addition, age differences were reduced for individuals with high verbal ability (significantly so for the control information). Although we are aware that ours is a controversial proposal, we believe it is reasonable to incorporate verbal ability differences into a working memory view (cf. Baddeley et al., 1985). This proposal is supported by findings of positive correlations between measures of verbal ability and working memory capacity (Baddeley et al., 1985, experiment 1; Hartley, 1986) and by the generally parallel patterns of age and verbal ability differences in the present study. A similar argument is at least implicit in Just and Carpenter (1987), who claimed that poor vocabulary skills can reduce working memory capacity (see also, Hunt, 1985).

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