Aging and interference in story recall

Iris Mund, Raoul Bell, and Axel Buchner

Heinrich-Heine-Universität Düsseldorf

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Abstract

Studies using a multiple-choice recognition test to examine age differences in the impairment of text comprehension due to distractors yielded inconsistent results. In the present study, participants were required to recall texts comprising unrelated, related, or no distractor words. Recall protocols were analyzed using a gist-based propositional scoring procedure. Older adults' story recall was clearly impaired by the presence of distractor material, whereas younger adults' recall performance was not. The findings suggest that older adults were more likely than younger adults to build up incorrect memory representations that comprise distractor concepts when distracting information was present.

Keywords: Text Recall, Prose Recall, Inhibition deficit theory, Inhibitory deficit theory, Text Comprehension, Cognitive Aging

Aging and interference in story recall

According to inhibitory deficit theory (Hasher & Zacks, 1988), cognitive aging is characterized by a reduction of inhibitory control over the contents of working memory. Most importantly for the present research, it is assumed that cognitive performance declines in old age because older adults fail to inhibit the processing of task-irrelevant extraneous information. One of the most frequently cited findings that supports inhibitory deficit theory is that older adults are more impaired than younger adults by the presence of distractor words when reading (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Dywan & Murphy, 1996; Feyereisen & Charlot, 2008; Kim, Hasher, & Zacks, 2007; Li, Hasher, Jonas, Rahhal, & May, 1998). In a typical experiment using the reading-with-distraction task, participants are required to read aloud short texts. In the experimental condition, to-be-ignored words in a distinct font style (upright font) are interspersed among the target text (printed in italic font). Usually, the increase in reading time in the distractor condition relative to a control condition without distractors is larger for older adults than for younger adults. Recent results show that these age differences are not solely due to sensory deficits of older adults, but arise from deficits in higher cognitive processes (Mund, Bell, & Buchner, in press). Mund et al. examined whether the age differences in distractibility prevail when visual acuity is equated between age groups. A priori, it seemed possible that older adults with sensory problems may fail to discriminate between target and distractor material at a perceptual level because they fail to see the subtle differences between different font styles. However, although visual acuity reduction increased interference somewhat, it did not eliminate the large age differences in distractibility as measured by the reading-time difference between the distractor condition and the control condition.

Another problem with interpreting the age differences in the slowing of reading time due to distractor words is that reading times of older and younger adults may already differ in the control condition in which no distracting information is present. In such cases the age-related increase in reading times in the distractor condition could be attributed to general age-related slowing rather than to a problem with interference control. There are only two studies that take age-related slowing into account by reporting the proportional increase in reading time relative to the baseline control condition (Kim et al., 2007; Mund et al., in press).[1] In one study the age difference in distractibility persisted in this analysis (Mund et al., in press), in the other it disappeared (Kim et al., 2007). Another problem when interpreting age differences in the slowing of reading speed is that old age may be associated with increased emphasis on accuracy as opposed to processing speed (Brébion, 2001, 2003). It is therefore conceivable that older adults put more emphasis on text comprehension while younger adults put more emphasis on reading speed. If this were true for the reading-with-distraction task, then older adults would read more slowly, and their reading times would increase disproportionally in those conditions in which text comprehension is complicated by the presence of meaningful distractors. Thus, the age differences in the increase in reading times due to distractor material cannot be unambiguously interpreted unless text comprehension is also assessed.

In most studies examining age differences in the reading-with-distraction task, text comprehension is assessed using a multiple-forced choice (MFC) text recognition test. In this test, participants are required to identify previously read target words among new words and previously ignored distractor words. Two findings from the MFC text comprehension test support inhibitory deficit theory. First, the decrease of memory for the target words in the distractor condition relative to the control condition is larger for older than for younger adults. Second, older adults make more intrusion errors (i.e., choose the previously to-be-ignored distractor more often) than younger adults.

However, evidence from the MFC recognition test in favor of the inhibitory deficit account is much less compelling than generally thought. Table 1 shows all studies we know of in which tests of statistical significance of age differences in the MFC recognition test were reported. Only two out of thirteen experiments found that the presence of distractor words impaired the ability to detect the target word to a greater extent in older adults than in younger adults. Only three studies out of nine found an increase of intrusions from the to-be-ignored material in old age. In sum, these results would be consistent with the assumptions that age differences in distractibility in the reading-with-distraction task are either particularly small or do not exist at all (considering that one out of twenty statistical tests to the conventional level of $\alpha = .05$ would be significant due to chance, and assuming that there may be a publication bias towards reporting significant age differences in the predicted direction). The lack of reliable age differences in text comprehension is especially problematic for inhibitory deficit theory given that the interpretation of the age-related increase of reading times in the distractor condition is also difficult due to problems such as how to take age-related slowing into account adequately. The inconsistent outcome of the studies examining text comprehension with the MFC recognition test may be due to the poor psychometric properties of this test (Darowski et al., 2008). As a first step, one may thus recommend that the psychometric properties of the text-comprehension test should be improved (e.g., by increasing the number of items).

However, at a more general level, one may raise the question whether a MFC recognition test is ideal for measuring text comprehension. When reading, we usually direct our attention to, and subsequently remember the *meaning* of the text rather than the specific wording, that is, the perceptual components of a text. Most theories of text comprehension (McNamara & Magliano, 2009) assume that the memory representations for texts can be best described as a connectionist semantic network, consisting of nodes and links varying in activation strength. This is in line with working memory models such as the embedded-processes model (Cowan, 1995, 1999) which imply that the mental representation of the text is established by directing the focus of attention towards the semantic content of the words in long-term memory. One of the most important functions of the attentional component of working memory is its capacity to form new associations between activated memory representations (cf. Oberauer, 2005a, 2005b). When reading, the focus of attention serves to bind together activated semantic representations to establish new links between the semantic concepts, resulting in the construction of a mental representation of the meaning of the target text. The MFC recognition test may not be the best method to assess text comprehension and the subsequent retention of meaning for several reasons. This is so because participants are required to identify the target word among false alternatives that differ from the target word at a perceptual-lexical level, but not (or only marginally) at a semantic level (e.g., “digging tools” vs. “digging equipment”). Failing to distinguish between these perceptually and lexically different but semantically equivalent alternatives is no definite evidence for an impairment in text comprehension. It follows from these considerations that a potentially more adequate measure of text comprehension should be particularly sensitive to the semantic content of the text rather than to its surface features. It has long been known that free recall has these properties (e.g., Srinivas & Roediger, 1990), but none of the published reading-with-distraction studies we know of has used a free recall test to assess the mental representation of the whole texts.[2] Therefore, we examined age differences in the reading-with-distraction paradigm using a memory test requiring free recall of whole texts. As will be shown in the *Discussion* section, the free recall test used here also yields a more reliable memory measure than the MFC recognition test, which helps solving the problem explicated in the preceding paragraph.

Three conditions were contrasted, a *control* condition, in which the texts were presented continuously, an *unrelated* distractor condition, in which the distractor words were unrelated to the meaning of the target text, and a *related* distractor condition, in which the target words were related to the meaning of the target text. As in other studies examining age differences in text comprehension (e.g. Johnson, 2003; Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine-Morrow, Shake, Miles, & Noh, 2006), we analyzed the number of propositions that were correctly recalled, using a gist-based scoring criterion. This allowed us to assess whether participants had an accurate representation of the *meaning* of the target text independent of its surface structure (Turner & Greene, 1987). We were especially interested in how the distractors would corrupt the mental representation of the target text in younger and older adults.

Method

Participants

47 older adults and 46 younger adults participated in the experiment. Data from three participants (two older adults and one younger adult) with a diagnosis of "mild cognitive impairment" in the DemTect (a sensitive dementia screening test; Kalbe et al., 2004) were excluded from data analysis. The remaining 45 older adults (30 women) ranged in age from 60 to 82 years (M = 68, SD = 5). The remaining 45 younger adults (26 women) ranged in age from 19 to 30 years (M = 24, SD = 3). Younger adults had more years of education than older adults, $F(1,88) = 15.45$, $p < .01$, $\eta^2 = .15$, but older adults performed better on a vocabulary test (MWT-A; Lehrl, 1989) than younger adults, $F(1,88) = 9.41$, $p < .01$,

$\eta^2 = .10$. Older and younger adults did not differ with respect to their self-assessed overall contentment with life, $\chi^2(1) = 1.70$, $p = .19$. All participants were native German speakers. None of the participants had a history of heart attack, stroke, brain trauma, alcoholism, Parkinson's disease, or pulmonary emphysema or had taken medication that could influence cognitive functioning.

Materials

The reading-with-distraction task requires discriminating font styles (typically upright vs italic in an unfamiliar font) that may be hard to distinguish with decreased visual acuity. Previous research has shown that age-related sensory decline may increase interference from upright distractors in italic text to some degree, but also that the age differences in the reading-with-distraction task cannot be fully explained by age differences in sensory acuity. In order to make sure that possible age differences in distractibility cannot be attributed to age differences in the failure to discriminate font styles at a perceptual level, we used glasses with partial occlusion filters (Ryser Optik; St. Gallen, Switzerland) to artificially reduce younger participants' visual acuity to the acuity measured in the group of older participants. This method has proven successful in previous studies (Lindenberger, Scherer, & Baltes, 2001; Mund et al., in press). Specifically, there are several types of partial occlusion filters that reduce visual acuity to different degrees. Younger participants were tested with filters that lowered their visual acuity to that of a (randomly) matched older adult. Visual acuity was assessed using a well established and validated visual computerized screening test (FrACT; Bach, 2007) with good psychometric properties. The test uses simple Landolt C optotypes and thus allows measuring "pure" visual acuity not confounded by higher cognitive processes that would be involved in an acuity test with, for instance, to-be-read words, sentences, or longer texts. The FrACT was run on the same (24 inch) computer monitor that was used for the experiment proper. Both age groups performed the FrACT before (pretest) and after visual acuity adjustment (posttest). A chin rest and a forehead rest were used to ensure that participants had a viewing distance of 110 cm to the computer screen during the entire experiment.

For the reading-with-distraction task, we used the same 20 texts as in Mund et al.'s (in press) study (dictation texts selected from school books used in 7th or 8th grade). All texts were 60 words long. On average, each text comprised 5 sentences (*SD* = 1) and 25 propositions (*SD* = 3). As in previous studies

(Connelly et al., 1991; Kim et al., 2007), the to-be-read target texts were presented in black italic Courier font on a white background. Each character subtended about 0.29° vertically and 0.21° horizontally. Fifteen texts were randomly selected as target texts, five in each of three distractor conditions (*continuous control, unrelated, related*). The texts were randomly assigned to the conditions on an individual basis. In the *continuous control* condition, the target texts were written continuously without distractor words. In the conditions with distracting material 30 distractor words (3 unique distractor words repeated 10 times) written in upright font were randomly interspersed into the target text with the constraint that no distractor word followed another distractor word directly and that the first and the last word of the text were no distractor words. For three nouns of each text, two semantically related words were selected (e.g., *Dschungel* [jungle] and *Tropenwald* [tropical forest] were selected for *Regenwald* [rain forest], and *Kopfschmerzen* [headache] and *Zahnschmerzen* [toothache] were selected for *Bauchschmerzen* [stomachache]). One of these three alternatives was randomly selected for being used as an italicized target word that appeared at the correct position in the text. In the *related* distractor condition, one of the other two alternatives was randomly selected to be used as a distractor word, and the other was used as a control word for the analysis of the number of intrusions (see the *Procedure* section). In the *unrelated* distractor condition, the distractor words (and control words) were drawn from the five texts that were not selected for presentation. The texts were presented in random order.

Procedure

Participants were tested individually. They were required to read out loud the text presented on the computer screen. Two short sentences—one sentence comprising irrelevant distractor words and one without distractor words—were presented to familiarize the participants with the task. In a practice trial, participants read a complete text with *related* distractor words. The practice trial was followed by the 15 experimental trials. Each trial started with a countdown. Then the text appeared at the center of the screen. Participants were required to read out loud the italicized text without making pauses and without making errors. They were advised to ignore all words printed in upright font. When participants had read the last word of the text, reading time was recorded.

The main difference between the present study and Mund et al.'s (in press) study or other studies using the reading-with-distraction task is in the way in which text comprehension was assessed. The present study is the first study we know of in which free recall of whole texts was used, whereas most previous studies used an MFC recognition test to assess age-related effects of distractor words on text comprehension (we explicate in the Introduction why free recall is more appropriate than the MFC recognition test). A question mark that appeared in the middle of the screen was the signal for participants to recall the target text with as much detail as possible. Participants' answers were recorded by the computer's built-in microphone. When participants felt that they could not remember any more details, they gave the experimenter a signal to initiate the next trial.

For scoring purposes, a propositional analysis was performed on the texts using the system of Turner and Greene (1987) that is based on the text-comprehension model of Kintsch and van Dijk (1978). For instance, the sentences "The Meyers do not care about housekeeping. They love dirt." were decomposed into the propositions (CARE ABOUT, A: THE MEYERS, O: HOUSEKEEPING), (NEGATE, (CARE ABOUT, A: THE MEYERS, O: HOUSEKEEPING)) and (LOVE, A: THE MEYERS, O: DIRT). Participants' answers were transcribed and compared to the template text bases using a gist-based scoring criterion. Thus, propositions comprising synonyms of to-be recalled words were scored correct. To illustrate, if a participant would have remembered "The Meyers do not care about housekeeping. They like filth.", all of the propositions would have been scored as correct. To increase the reliability and validity of the scoring procedure, we used the *Projekt Deutscher Wortschatz* database (http://wortschatz.uni-leipzig.de/) to identify synonyms. The database is based on a huge collection of texts from various sources (e.g., newspaper articles, webpages) and thus represents a large portion of current-day word usage (see Biemann, Bordag, Heyer, Quasthoff, & Wolff, 2004). To evaluate the reliability of the propositional scoring procedure, the 150 recall protocols of ten randomly selected participants (5 younger and 5 older adults) were scored by an independent rater. Inter-rater agreement, as assessed by the kappa-coefficient (Cohen, 1960), was $\kappa = .94$ (i.e., "almost perfect"; Landis & Koch, 1977).

In addition to the analysis of the propositional content of the recall protocols, a levels analysis was conducted according to the procedure outlined by Dixon, Simon, Nowak, and Hultsch (1982). This procedure is based on the assumption of Kintsch and van Dijk (1978) that each text consists of propositions which are connected and hierarchically ordered. A proposition *B* is subordinated to another proposition *A* when proposition *A* is either embedded in proposition *B* or when proposition *A* contains an argument that is repeated in proposition *B*. With proposition *A* assigned to the level *n*, the subordinated proposition *B* obtains the level *n* + 1. After decomposing the stories into the propositions contained, we specified the hierarchical structure of each story according to these rules. Following the procedure of previous studies (e.g. Adams, Smith, Pasupathi, & Vitolo, 2002), we subsequently summed the original raw scores for levels 1 and 2 representing the main ideas of the text and all levels of 3 and higher representing the details of the text in order to simplify the levels analysis.

To detect distractor intrusions, the words of the recall protocols were automatically compared to the word-stems of the distractor words and the control words using a computer program. If a word in the recall protocol matched the word-stem of a distractor word, the word was scored as an intrusion. However, not all distractor intrusions may be due to aftereffects of distractor presentation. In the *related* distractor condition, participants may paraphrase and add new information that may coincidentally match the distractor words. To control for spontaneous use of distractor words, we also analyzed intrusions from control words that were not presented as distractors. In both distractor conditions, it was randomly determined whether a specific word would be used as a distractor or as a control word. Therefore, differences in the rate of intrusions between these two types of words can only be attributed to aftereffects of distractor word presentation in the reading phase.

Design

A 2 × 3 design was used with group (*younger* vs. *older*) as between-subject factor and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as within-subject factor. The dependent variables were reading time, the proportion of correctly recalled propositions, and the number of intrusion errors. Given a sample size of 90 and assuming a correlation of $\rho = .5$ among the levels of the within-subject factor, an effect of size $f = 0.17$ (i.e., between small and medium effects as defined by Cohen, 1988) could be detected for the interaction between group and distractor condition with a probability of $1 - \beta = .95$ (Faul, Erdfelder, Lang, & Buchner, 2007). A multivariate approach was used for all within-subject comparisons. In the present application, all multivariate test criteria correspond to the same (exact) *F*-statistic, which is reported. Partial η^2 is reported as a measure of the size of an effect. The level of α was set to .05 for all analyses.

Results

Treatment check of the visual acuity manipulation

In the pretest (when younger adults were tested *without* partial occlusion filters), visual acuity was worse for older (*Md* = 0.88) than for younger adults (*Md* = 1.07), $z = -5.99$, $p < .01$. In the posttest (when younger adults were tested *with* partial occlusion filters), visual acuity was the same for older (*Md* = 0.92) and younger adults (*Md* = 0.85), $z = -1.65$, $p = .10$ (Figure 1), confirming that we succeeded in equating visual acuity between older and younger adults. Thus, age differences in distractibility cannot be attributed to older adults' failing to see the differences between italic and upright font because of age differences in visual acuity.

Reading times

A 2 × 3 MANOVA with age group (*younger* vs. *older*) and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as independent variables revealed a significant main effect of distractor condition, $F(2,87) = 224.75$, $p < .01$, $\eta^2 = .84$ (Figure 2). Orthogonal contrasts showed that participants read more slowly in the *unrelated* distractor condition than in the *continuous control* condition $F(1,88) = 415.94$, $p < .01$, $\eta^2 = .83$, and more slowly in the *related* than in the *unrelated* distractor condition, $F(1,88) = 45.84$, $p < .01$, $\eta^2 = .34$. There was also a main effect of age group, $F(1,88) = 13.31$, $p < .01$, $\eta^2 = .13$, that was qualified by an age group × distractor condition interaction $F(2,87) = 10.69$, $p < .01$, $\eta^2 = .20$. The interaction between age group and the variable contrasting the control condition with the two distractor conditions combined was significant, $F(1,88) = 20.25$, $p < .01$, $\eta^2 = .19$, suggesting that older adults were slowed down more by the presence of distractor words than younger adults. The interaction between age group and the variable contrasting the *unrelated* distractor condition with the *related* distractor condition was not significant, $F(1,88) = 0.09$, $p = .77$, $\eta^2 < .01$, suggesting that older adults were *generally* more impaired by distracting information. Remarkably, reading speed did not differ between older and younger adults when the texts contained no distracting material, $F(1,88) = 1.36$, $p = .25$, $\eta^2 = .02$. Large age differences emerged in the *unrelated* distractor condition, $F(1,88) = 16.10$, $p < .01$, $\eta^2 = .16$, and in the *related* distractor condition $F(1,88) = 14.58$, $p < .01$, $\eta^2 = .14$. The fact that age differences in reading speed were confined to the distractor conditions shows that the age difference in reading times in the distractor conditions cannot be attributed to age-related slowing and must be due to age-related problems in interference control. To facilitate the comparison of the results of the present studies with previous studies (Duchek, Balota, & Thessing, 1998; Kim et al., 2007; Mund et al., in press), we also analyzed the proportional increase in reading time in the distractor conditions relative to the control condition (that is, reading times in the distractor conditions divided by the reading time in the control condition). As expected, this analysis revealed a significant effect of age group on the proportional increase in reading time due to the presence of distractor words, $F(1,88) = 14.06$, $p < .01$, $\eta^2 = .14$.

Propositional recall

Figure 3 shows the proportion of correctly recalled propositions. A 2 × 2 × 3 MANOVA with age group (*younger* vs. *older*), level (*main ideas* vs. *details*), and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as independent variables revealed a significant main effect of age group, $F(1,88) = 30.15$, $p < .01$, $\eta^2 = .25$, suggesting that older adults recalled fewer propositions than younger adults. There was also a main effect of distractor condition, $F(2,87) = 11.71$, $p < .01$, $\eta^2 = .21$. Orthogonal contrasts showed that there was no significant difference between the *unrelated* distractor condition and the *continuous control* condition, $F(1,88) = 0.53$, $p = .47$, $\eta^2 = .01$, but participants recalled more propositions in the *unrelated* distractor condition than in the *related* distractor condition, $F(1,88) = 21.86$, $p < .01$, $\eta^2 = .20$. Moreover, there was a main effect of level $F(1,88) = 694.34$, $p < .01$, $\eta^2 = .89$, replicating the prevailing finding that the main ideas of texts are more likely to be recalled than the details of the texts

(Adams et al., 2002; Dixon et al., 2004). This level effect was reduced in older adults as indicated by the significant interaction between age group and level $F(1,88) = 4.84$, $p = .03$, $\eta^2 = .05$. Consistent with other findings (e.g. Dixon et al., 1982; Meyer & Rice, 1981; Stine, Wingfield, & Poon, 1986), it seems that younger adults are better than older adults at discriminating between the (presumably more important) main ideas and the (less important) details of the texts, resulting in a reduction of the level effect. All other interactions involving the level-variable did not attain the conventional level of significance.

The most interesting question was whether we would find age differences in distractibility, i.e. in the impairment of propositional recall due to irrelevant information. Consistent with predictions derived from inhibitory deficit theory, the age group × distractor condition interaction was significant, $F(2,87) = 8.32$, $p < .01$, $\eta^2 = .16$. Older adults' propositional recall was clearly impaired by unrelated distractor words, $F(1,44) = 7.89$, $p = .01$, $\eta^2 = .15$, and was even more impaired by related distractor words than by unrelated distractor words, $F(1,44) = 12.09$, $p < .01$, $\eta^2 = .22$. Younger adults, in contrast, showed an increase in propositional recall in the *unrelated* distractor condition in comparison to the *continuous control* condition $F(1,44) = 8.71$, $p = .01$, $\eta^2 = .17$. This paradoxical effect can be explained by assuming that younger adults successfully increased their reading efforts as a response to the increased reading difficulty caused by the distractors relative to the *control* condition. In particular, they may have attended more to the meaning of the target text in the *unrelated* distractor condition than in the *control* condition to avoid interference. Note that in the *unrelated* distractor condition, concentrating on the meaning of the text may be an efficient countermeasure against interference because it helps to discriminate between target and distractor materials that differ markedly in their semantic properties. This compensatory strategy is not useful in the *related* distractor condition because of the semantic relatedness of the distracting material. This may be the reason why younger adults' recall in the *related* distractor condition decreases when compared to the *unrelated* distractor condition. Older adults, however, seem to be less able than younger adults to adjust their reading efforts to support interference avoidance, which results in a significant decrease of memory performance in the *unrelated* distractor condition as compared to the *continuous* control condition. However, the global interaction of age group and distractor condition is not solely due to younger adults' enhanced memory performance in the *unrelated* distractor condition. If only the *continuous control* condition and the *related* distractor condition were included in this analysis, the interaction between age group and distractor condition persists, $F(1,88) = 9.57$, $p < .01$, $\eta^2 = .10$. Thus, older adults' propositional recall was clearly impaired by the distracting material, whereas younger adults' recall performance was not.

The analysis of the intrusion errors also revealed evidence for age differences in interference control (Figure 4). Older adults produced more intrusions from related distractor words than younger adults, $F(1,88) = 9.10$, $p < .01$, $\eta^2 = .09$. In contrast, very few control words were produced and there were no age differences in the production of control words, $F(1,88) = 0.05$, $p = .83$, $\eta^2 < .01$. Thus, intrusions from related distractor words cannot simply be attributed to older adults remembering less and paraphrasing more than younger adults. Intrusions from unrelated distractor words were less frequent than intrusions from related distractor words. This was to be expected given that these unrelated distractor words did not fit the target text at all. Nevertheless, the same data pattern was obtained for unrelated distractor intrusions and for related distractor intrusions. Older adults made more intrusions from unrelated distractor words than younger adults $F(1,88) = 14.11$, $p < .01$, $\eta^2 = .14$, but there was no age difference in the number of intrusions from unrelated control words (that were not presented as distractors), $F(1,88) = 0.65$, $p = .42$, $\eta^2 = .01$.

Discussion

The present study revealed pronounced age differences in reading with distraction, as predicted by inhibitory deficit theory (Hasher & Zacks, 1988). Age differences were equally pronounced in the *unrelated* and the *related* distractor condition. This suggests that these age differences can be attributed to general problems with interference control rather than to specific problems with rejecting related material (e.g., a broader activation of semantically related concepts in older adults' working memory).

Consistent with previous studies, older adults were slowed down more by the presence of distractor words than younger adults when reading. This finding has been previously attributed to older adults' decreasing visual capabilities that may increase distractibility in the reading-with-distraction task because this task requires discrimination of subtle perceptual differences between target and distractor font styles (Bell & Buchner, 2007; Bell, Buchner, & Mund, 2008; Burke & Osborne, 2007; Burke & Shafto, 2008). The present study can rule out this alternative explanation of age differences in reading with distraction, because visual acuity was equated between older and younger adults. Thus, the increase in distractibility in older adults cannot be attributed to age-related sensory decline. This replicates the finding of Mund et al. (in press) that age differences in the original version of the reading-with-distraction task persisted when age differences in visual acuity were taken into account by adjusting younger and older adults' visual acuity so that there were no differences in visual acuity across both age groups. Age differences in the increase in reading times due to the presence of distractor words persisted when cognitive slowing was taken into account by analyzing the proportional increase in reading times in the distractor conditions relative to the control condition, which also replicates the findings of Mund et al. It is reassuring to see that the age difference in the slowing of reading by distractors persists when a free-recall test following each reading phase required both younger and older adults to focus on text comprehension.

The most important question was whether we would find evidence that older adults' memory for the texts would be more impaired by the distractor words than that of younger adults. Consistent with the hypotheses derived from inhibitory deficit theory, we found that the decrease in propositional recall in the distractor conditions was more pronounced for older adults than for younger adults, and that older adults produced more intrusions from both related and unrelated distractor words than younger adults. Given that previous studies examining age differences in text comprehension with a MFC recognition test yielded highly inconsistent results (see Table 1), it seems notable that we found evidence for an increased distractibility of older adults in all dependent variables. The simplest explanation of this fact together with the inconsistency in previous studies is that the psychometric properties of the propositional-recall score and the MFC recognition test score differ. The reliability of the MFC recognition test score is comparably poor. For instance, in Experiment 1 of Mund et al. (in press), Cronbach's alpha across age groups was .40 in the *control* condition and .48 in the *related* distractor condition. Reliability was equally low in other studies using the reading-with-distraction task. For instance, Darowski et al. (2008) reported a reliability of .42 in the *control* condition and of .41 in the *related* distractor condition. In contrast, the reliability of the propositional-recall score obtained in the present study was .71 in the *control* condition and .79 in the *related* distractor condition. Thus, the failure in many studies to obtain significant age differences in the decrease of text comprehension due to the presence of distractor words might potentially be due to the low reliability of the MFC recognition test score rather than to preserved inhibitory functioning in older adults. We think it reasonable to assume that the MFC recognition test's reliability is low because the observed MFC recognition test score can be conceived of as a combination of a small text comprehension true score and a large measurement error component.

However, the present results not only confirm the existence of age differences in the impairment of text comprehension due to verbal distractors; they also allow for a more detailed assessment of distractibility in the reading-with-distraction task. The age-related decrease of propositional recall in the distractor conditions suggest that older adults were less able than younger adults to establish a mental representation of the target text when distractor words were present. Due to deficits in inhibitory control, older adults may be more likely to process distracting material than younger adults, which may draw attentional resources away from the binding of the semantic concepts that constitute the target text. The finding that younger adults had even better recall performance in the *unrelated* distractor condition than in the *control* condition suggests that the age differences in interference may, in part, be due to younger adults' compensatory strategy efforts to avoid interference. In the *unrelated* distractor condition, younger participants may place greater emphasis on text comprehension because this helps them to reject the unrelated distractor words. This strategy cannot help in the *related* distractor condition, which may result in a drop in propositional recall in this condition when compared to the *unrelated* distractor condition. This interpretation is consistent with the finding that younger adults are better able than older adults to apply flexible strategies according to the particular demands of a reading task (Stine-Morrow et al., 2006). Thus, the more sensitive text-comprehension test used in the present study allowed us to detect age differences in the strategic use of semantic encoding strategies that would not have been detected by the insensitive MFC recognition test. The finding suggests that future studies should take into account the participants' active role in interference avoidance by examining whether older adults differ in the use of strategies that help them to cope with the demands of selective-attention paradigms.

Older adults also made more intrusions from related distractor words than younger adults. This finding could be explained by assuming that the irrelevant information enters the focus of attention, where it intrudes into ongoing cognitive operations such as binding word concepts to propositions. In the related distractor condition, the semantic representations of the target words and the distractor words differ only marginally or are even identical. Potter and Lombardi (1990) examined interference in a similar paradigm. They required participants to learn sentences. Before sentence recall, participants were required to read a list of words that comprised a synonym of one of the words in the sentence. These lure words were frequent intrusions, but only when they were semantically related to the meaning of the sentence. Potter and Lombardi suggested that during recall, the sentence had to be regenerated from a conceptual representation of the meaning of the sentence, using recently activated lexical entries. The intrusions of related distractor words in the reading-with-distraction task can be explained using the same assumptions. Some of the related distractor words are synonyms of words in the to-be recalled text (i.e., they share the same conceptual representation). If processing of the distractor word is not suppressed, the lexical representation of the distractor word may be more activated than the lexical representation of the target word given that the distractor word was presented more frequently than the target (ten times vs. once). Thus, intrusions from related distractor words could be explained by assuming that participants regenerate the to-be recalled story from a correct conceptual representation of the target text, using the highly accessible lexical entries of the distractor words.

However, this explanation cannot be applied to the finding that older adults made more intrusions from *unrelated* distractor words than younger adults. In this condition, distractor words did not fit the to-be recalled texts at all. Therefore, this suggests that the semantic concepts of the distractor words were integrated into the mental representation of the text. To illustrate, instead of remembering "Each point of the globe can be reached. We can wake up in a different country every morning because airplanes and trains are always available...", an older participant included as an intrusion the unrelated distractor word "rain forest" by remembering "It is always possible to go everywhere via train and airplane, to go for a walk in the rain forest or to wake up in a different country every morning...". Note that—at least in terms of standardized effect size, the age difference in the number of intrusion errors were equally large in the *unrelated* distractor condition and in the *related* distractor condition, suggesting that older adults may fail to prevent distractor content from entering the focus of attention. As a consequence, the distractor information is at least occasionally built into the mental representation of the target text.

In summary, we used a propositional scoring procedure to analyze how distractor words interfere with story recall. Older adults showed a more pronounced decrease of propositional recall due to the presentation of distractor words than younger adults. This suggests that older adults were less able than younger adults to establish a correct mental representation of the text when distractor words were present. The analysis of distractor intrusions suggested that older adults were more likely than younger adults to build up incorrect memory representations that comprise distractor information. We conclude that there are pronounced age differences in the impairment of text comprehension by distracting information.

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Footnotes

[1] Duchek et al. (1998) report an analysis of proportional increase in reading time relative to the control condition, but they report only the global interaction between distractor condition and group, and they examined younger adults, older adults, and Alzheimer's patients. Therefore, it is unclear whether the significant interaction between group and condition can be attributed to the effects of normal aging.

[2] Note that Li et al., (1998) converted the MFC questions into a cued recall task, in which participants were asked to recall the target word. Obviously, this procedure is also not suited to reveal age differences in the susceptibility to interference within the mental representation of a whole text, i.e. a network of activated semantic concepts and their connections.

Author Notes

Iris Mund, Raoul Bell, and Axel Buchner, Department of Experimental Psychology, Heinrich-Heine-University, Düsseldorf, Germany. Correspondence concerning this article should be addressed to Iris Mund, Institut für Experimentelle Psychologie, Heinrich-Heine-Universität, D-40225 Düsseldorf, Germany. Electronic mail may be sent to iris.mund@uni-duesseldorf.de.

Table 1

Results of the MFC-recognition test used by previous studies regarding age differences in susceptibility to interference. “Yes” indicates findings that suggest an age-related increase in distractibility (i.e., a significant interaction between age group and distractor condition), “No” indicates the absence of age differences in distractibility. Studies marked with a hyphen (-) did not report the relevant comparison of distractibility as a function of age group in the particular variable.

Authors	Year	Experiment	Age Difference in Memory for Target Words	Age Difference in Intrusion Errors
Connelly, Hasher & Zacks	1991	1	No	No
		2	No	No
Carlson, Hasher, Connelly & Zacks	1995	1	No	No
		2	No	No
		3	Yes	Yes
Dywan & Murphy	1996	1	No	Yes
Duchek, Balota & Thessing	1998	1	No	No
Phillips & Lesperance	2003	1	No	-
Kemper & McDowd	2006	1	No	-
Kemper, McDowd, Metcalf & Liu	2008	1	Yes	-
Feyereisen & Charlot	2008	1	No	-
Mund, Bell & Buchner	2010	1	No	No
		2	No	Yes

Figure Captions

Figure 1: Visual acuity in Snellen decimals for the two groups in both visual acuity tests. Each marker represents the visual acuity of one participant.

Figure 2: Mean reading time as a function of distractor condition and group. The error bars represent the standard errors of the means.

Figure 3: Mean percent of correctly recalled propositions as a function of distractor condition and group. The error bars represent the standard errors of the means.

Figure 4: Mean number of intrusion errors as a function of word type and group. Left panel: Mean number of intrusion errors in the *related* distractor words condition. Right panel: Mean number of intrusion errors in the *unrelated* distractor words condition. The error bars represent the standard errors of the means.

Figure 1

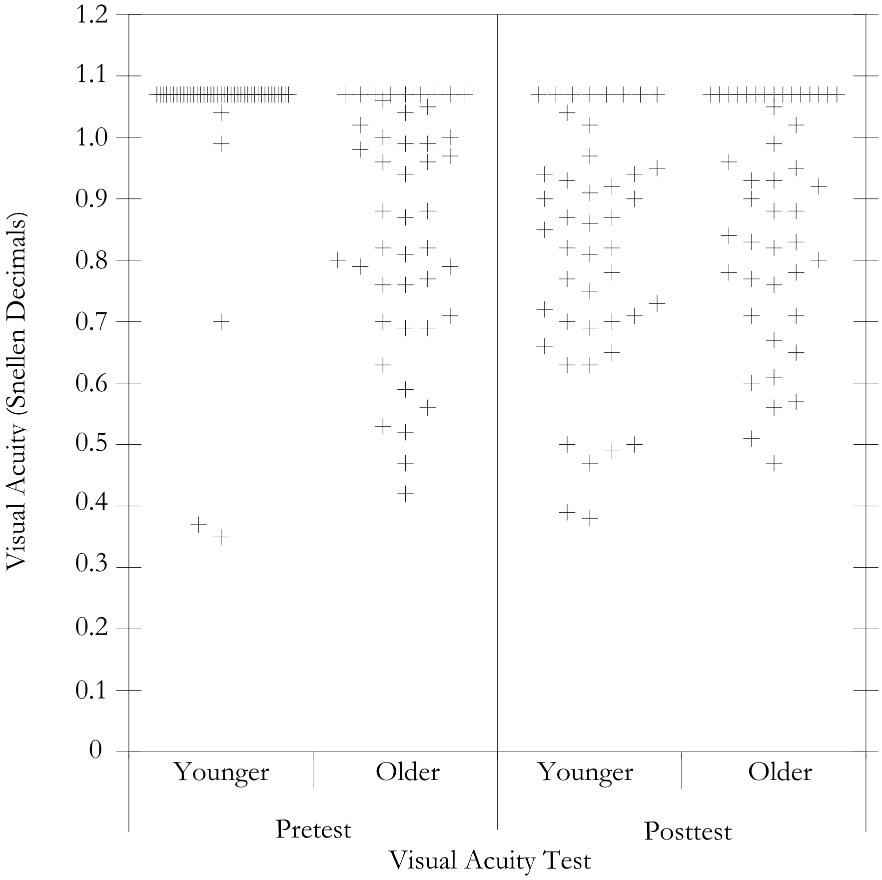

1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Visual Acuity (Snellen Decimals)
Younger
Older
Younger
Older
Pretest
Posttest
Visual Acuity Test

Figure 2

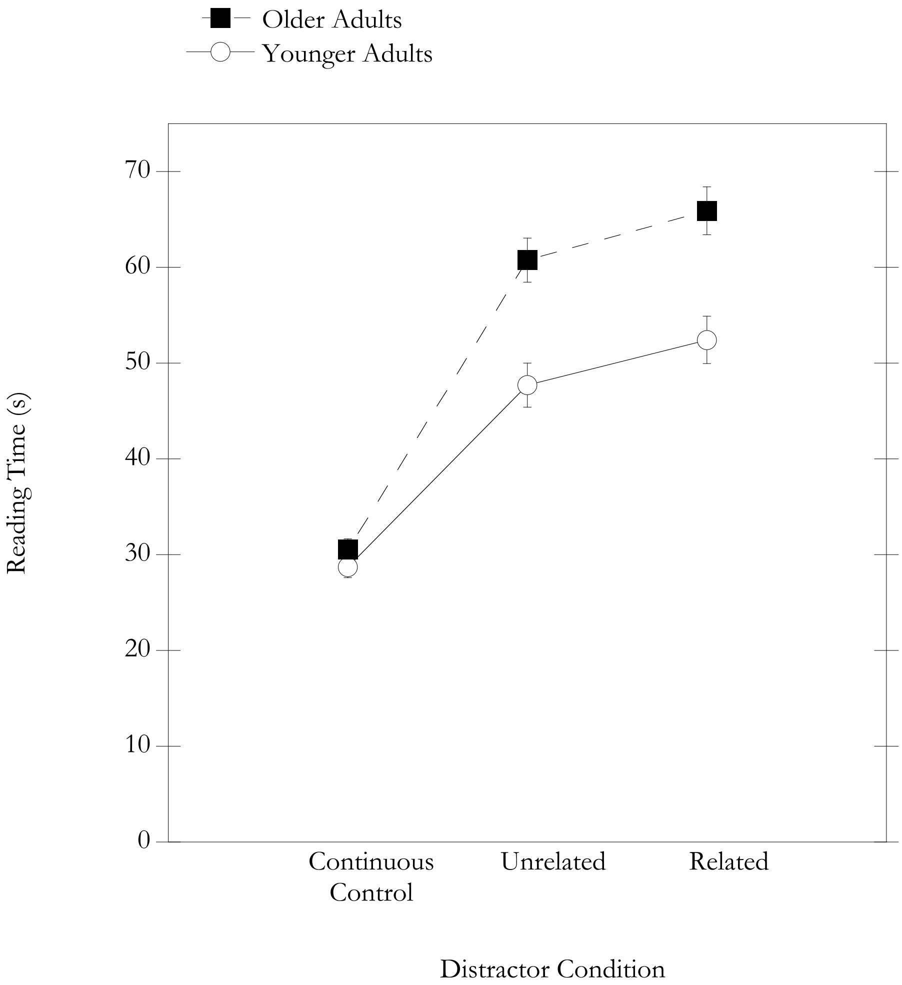
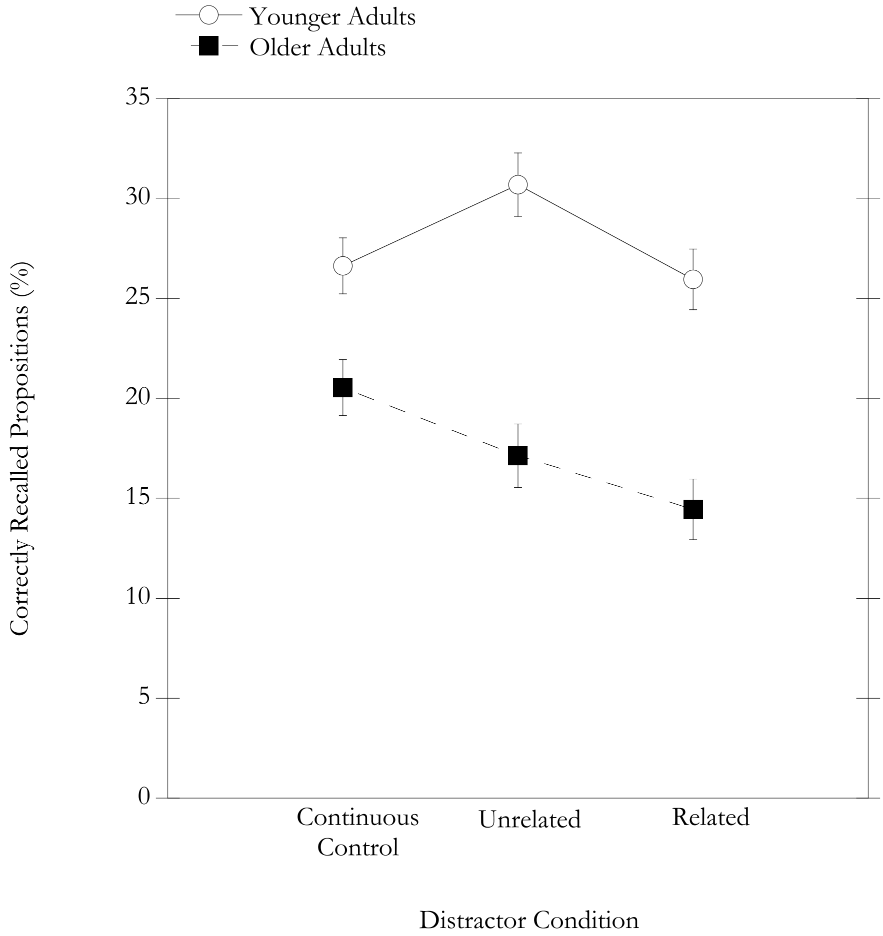
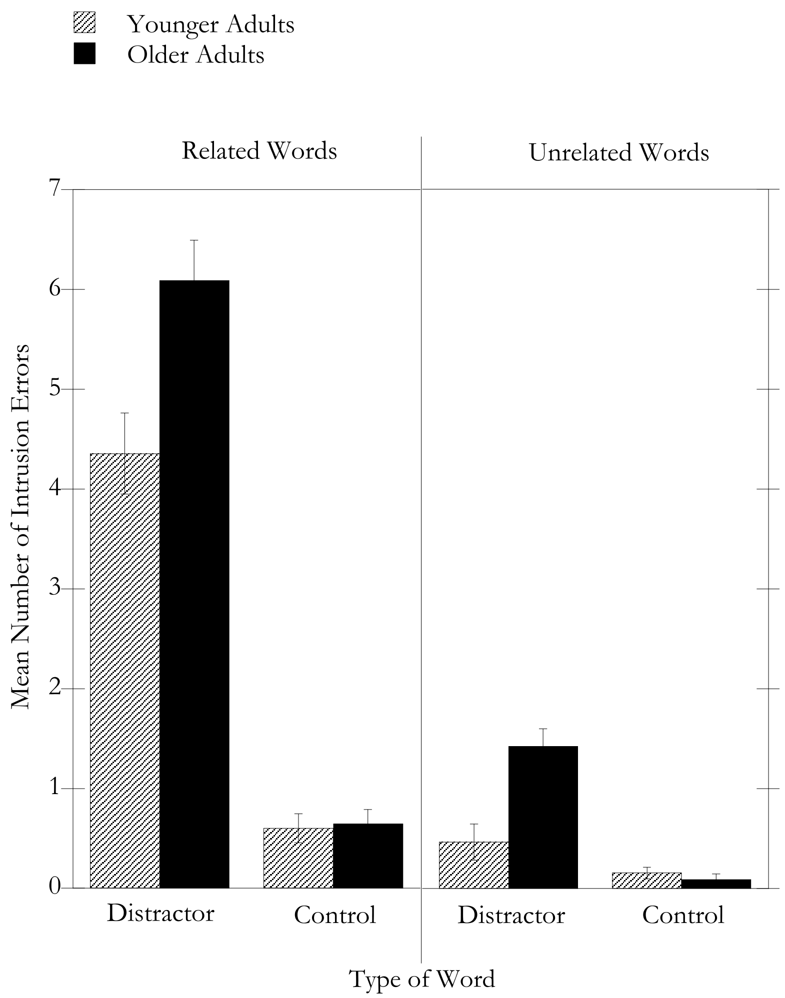

Older Adults
Younger Adults
Reading Time (s)
0
10
20
30
40
50
60
70
Continuous Control
Unrelated
Related
Distractor Condition

Figure 3



Younger Adults
Older Adults
35
30
25
20
15
10
5
0
Correctly Recalled Propositions (%)
Continuous Control
Unrelated
Related
Distractor Condition

Figure 4


Younger Adults
Older Adults
Related Words
Unrelated Words
7
6
5
4
3
2
1
0
Mean Number of Intrusion Errors
Distractor
Control
Distractor
Control
Type of Word