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Abstract:

We used eye-tracking technology to examine young and old adults' on-line performance in the reading in distraction paradigm. Participants read target sentences and answered comprehension questions following each sentence. In some sentences, single word distracters were presented in either italic or red font. Distracters could be related or unrelated to the target text. On-line measures including probability of fixation, fixation duration, and number of fixations to distracting text revealed no age differences in text processing. However, young adults did have an advantage over older adults in overall reading time and text comprehension. These results provide no support for an inhibition deficit account of age differences in the reading in distraction paradigm, but are consistent with Dywan and Murphy's (1995) suggestion that older adults are less able than young to distinguish target and distracter information held in working memory.

Text of paper:

Eye movements of Young and Older Adults while Reading with Distraction

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Eye movements of Young and Older Adults while Reading with Distraction

Hasher & Zacks (1988) (see also Zacks & Hasher, 1997; Zacks, Hasher, & Li, 2000) proposed that inhibitory mechanisms weaken with age and permit the intrusion of irrelevant thoughts, personal preoccupations, and idiosyncratic associations during language production and comprehension tasks. In a series of studies by Carlson, Hasher, Connelly, and Zacks (1995) and Connelly, Hasher, and Zacks (1991), readers were confronted with texts containing distracter words printed in different typefaces. When asked to read the texts aloud, older adults read more slowly and performed less accurately on comprehension tests than young adults. This pattern suggests that young adults are able to ignore the distracting material, whereas older adults are not able to ignore the distracting material, which slows their reading and renders them subject to comprehension deficits.

The inference of an age-related inhibitory breakdown in the Carlson et al. (1995) and Connelly et al. (1991) studies was based on a global measure of reading speed as well as from results of a multiple-choice comprehension test. However, subsequent studies indicated that these measures did not tell the whole story. For example, Dywan and Murphy (1996) observed that although older participants were more likely to choose the distracters as foils in a comprehension test, young adults were better able to recognize the distracters on a recognition test. This result is difficult to explain if the young adults are assumed to have been successful at inhibiting processing of the distracters. In another study, Multhaup, Hasher, and Zacks (1998) tested memory for target and distracter information using both a forced-choice recognition test and a sentence completion test. Young adults recognized more distracters than older adults; however, older adults used more distracters to complete the sentence fragments than did young adults. This mixed pattern of results casts doubt on the utility of indirect measures, based on memory performance, to infer differences in initial processing.

Studying the question at a different level of analysis, Philips and Lesperance (2003) tracked event-related brain potentials (ERPs) while young and older adults read sentences followed by probe words. The sentences contained 3 or 4 distracter words from the same semantic category. The probe words following the sentences were related in meaning to the sentence or to the distracters or to neither sentence nor distracters. For example, the sentence "The train *oak* is *maple* never on *pine* time" was probed with a semantically related word, *late*, a word related to the distracters, *tree,* or an unrelated word, *table*. The N400 ERP component, commonly interpreted as a measure of semantic priming, was recorded for the probe words. The N400 was predicted to show little activity in response to probe words related to the meaning of the sentences whereas the N400 should show increased activity in response to probe words unrelated to the meaning of the sentence. If the distracters were successfully ignored, a large N400 should result, comparable to that for unrelated probe words. If the distracters were not inhibited, little N400 activity should result, comparable to that for related probe words. The results revealed striking differences between young and older adults: young adults evidently processed the distracters, as indicated by reduced N400s to the distracter probe words. Older adults showed no priming for semantically-related words or for distracter words, as indicated by similar N400 patterns for all three types of words. The authors suggested that the distracters disrupted the older adults' processing of the sentences, rendering them "syntactically irregular and initially incoherent" (p. 136). However, this study, like those of Carlson et al. (1995), Connelly et al. (1991), and Multhaup et al. (1998), still provides only indirect evidence regarding the immediate processing of the distracters and target material.

Eye movement measurement is one approach that provides immediate, on-line assessment of visual information processing. It has supplanted other techniques for the study of immediate, moment-to-moment processes during reading (Rayner, & Pollatsek, 1987, 1989; Rayner, 1998). Techniques such as experimenter-control of word presentation times are highly artificial and may disrupt normal reading processes; other tasks, such as measuring self-paced reading times for words, phrases, or sentences, are less sensitive to linguistic, cognitive, and individual factors which affect reading. Eye movement patterns are sensitive to many factors including reading ability, text difficulty, and cognitive load.

In the present study, we used eye movement technology to assess moment-by-moment visual information processing of young and older adults while reading sentences including interspersed distracting text. Connelly, Hasher & Zacks's (1991) conclusion regarding inhibitory deficits among older adults was based primarily on longer total reading times in the presence of distracters for older compared to younger adults. Extending this logic to the present study, inhibitory-deficit theory predicts that older adults should spend more time fixating distracters than young adults if they are less able to inhibit processing of task-irrelevant information. Indeed, distinct patterns of eye movements should occur for young and older adults as a result of age-related inhibitory deficits.

Our design provided for examination of a number of factors that could be expected to affect inhibitory function. First, the distracting text was presented in either an italic font that differed from the target text, or in a font color different from the target text. Type of distracter (italic text, colored text) was designed as a manipulation of ease of detection; previous work has shown that for both young and old adults, selective attention to relevant information is facilitated when irrelevant information is easily identified as such (e.g., Farkas & Hoyer, 1980; Hoyer & Plude, 1982; Nebes & Madden, 1983; Plude & Hoyer, 1985). Thus inhibitory processes in selective attention should be more effective in the colored distracter condition than in the italic distracter condition, with age differences smaller in the former condition than in the latter.

We also investigated how the distracters would affect sentence processing by manipulating two characteristics of the text. First, we varied whether the distracters were or were not related in meaning to the sentences. All distracters could be detected by noticing that they violated morphosyntactic rules governing word order and phrase structure and were not good continuations of the sentence. In addition, we manipulated whether or not distracters which were semantic associates of other words from the sentence. Connelly et al. (1991) reported that older adults were more slowed than young when distracting text was related to their paragraph text. Based on their finding, we hypothesized that the processing of distracter words related in meaning to the sentence may be more difficult to inhibit (and so more likely to be fixated, and fixated for longer) than the processing of unrelated distracters, particularly for older adults.

Second, we varied whether or not a target word that immediately followed the distracter word could be predicted from the preceding sentence context using sentences created by Schwanenflugel and Shoben (1985) and used by Rayner and Well (1996). Rayner and Well found that skilled readers allocate less processing time to highly predictable target words; Mitzner, Radel, Filion, and Kemper (2002) reported that older adults' fixations to these target words did not vary with predictability, suggesting that they do not use target predictability to improve the efficiency of their processing. In the present context, it may be that older adults are unable to inhibit fixations to the target words, even when they are highly predictable. Young adults, in contrast, are expected to be able to inhibit processing of the predictable target words.

The presence of distracters is expected to disrupt other aspects of text processing as well. If older adults are less able to inhibit processing of irrelevant information, they may attempt to integrate distracter text into the meaning of the sentence. Such attempts would be evidenced by longer fixations on sentence text and more frequent left-ward regressions in the pattern of eye movements for older adults.

In addition to these on-line measures of text processing, we also included off-line measures to assess comprehension accuracy and recognition memory for target and distracter text, as well as total reading time. Although inhibitory deficit theory clearly predicts that older adults should be more likely to answer incorrectly with distracter information in comprehension tests and more likely to recognize distracter information in memory tests, there is little evidence to support this. Connelly et al. (1991) attempted to test these ideas but floor and ceiling effects prevented strong conclusions. Dywan and Murphy (1995) reported that older adults made more comprehension errors due to intrusions of distracter information, but that young adults were more likely to correctly recognize distracter text in a recognition memory test. These conflicting findings are re-examined in the present study.

Method

Eye fixation patterns of young and older adults were compared as they read sentences containing interpolated single-word distracters. Four measures were obtained from the eye fixation records: the probability of a fixation, first pass fixation times, leftward regressions, and total fixation times reflecting first pass fixations plus subsequent fixations arising from regressions and re-reading the sentence in whole or in part. Fixation and regressions to distracters, target words that followed the distracters, and words flanking the targets were examined.

Participants. Forty-nine older adults and thirty-five young adults participated. All older participants were community-dwelling adults who were recruited from a registry of prior research participants. All young participants were college-students recruited via postings on campus bulletin boards and class announcements. All participants were monolingual speakers of English. All were paid a modest honorarium for their participation.

To be included in the data analyses, participants were required to achieve at least 90% accuracy on questions testing their comprehension of control sentences that did not contain any distracters. This criterion was designed to exclude any participants with any general reading problems. Seventeen older adults and 3 young adults were excluded by this criterion; in addition, data from 8 older adults and 6 young adults was lost due to excessive eye tracking failures, leaving 24 older participants and 24 young participants in the experimental study.

The participants are described more fully in Table 1. Based on a 1-way ANOVA comparing age groups, the participants differed in reading habits as well as performance on the Digits Forward and Digits Backwards tests from the Wechsler Adult Intelligence Scales-Revised (Wechsler, 1981) and the Daneman and Carpenter reading test (Daneman & Carpenter, 1970). The older participants also scored higher than the young participants on the Shipley Vocabulary test (Shipley, 1940). An α level of .05 was set for this and all subsequent t and F tests.

Materials. There were 72 sets of sentences and probe questions. There were 12 variants of each sentence, differing in the predictability of the target word (high versus low), distracter type (none, related to the sentence, or unrelated), and the visual cue to the distracter (color, font). Many of the sentences were originally developed by Schwanenflugel and Shoben (1985) and used by Rayner & Well (1996); additional sentences were developed by Mitzner, Radel, Filion, & Kemper (2002). A target word occurred in each sentence; high and low predictability target words were contrasted in alternative versions of the sentence. On some trials, a distracter word appeared immediately prior to the target; the distracter was either related or unrelated in meaning to the sentence. The distracter, if present, was presented in a different font (italics) than the sentence or a different color (red) than the rest of the sentence (black). Target word predictability was determined by Schwanenflugel et al. or by Mitzner et al. based on a cloze procedure; high predictability targets were generated by at least 90% of respondents; low predictability targets were generated by less than 10% of the respondents. Target words were matched for word length and word frequency. The distracters were selected using the Nelson, McEvoy, & Schreiber (1998) norms; two were selected such that one was a highly associated with other words of the sentence and one was not associated with other words of the sentence. Care was taken to ensure that the pairs of distracters were matched for part of speech, word length, and word frequency and that they were not appropriate continuations of the sentence and could be detected by noticing that they violated semantic and morphosyntactic rules. A probe question accompanied each sentence. Examples are presented in Table 2.

Sentences were assigned to 12 stimulus lists such that each list contained 6 examples of each experimental condition but only 1 sentence from each set. In each list, 24 sentences did not have distracters, 24 had distracters distinguished by color, and 24 had distracters distinguished by font. In addition to the experimental sentences, each list contained 60 filler sentences of various syntactic forms; 20 without distracters, 20 with distracters distinguished by color, and 20 with distracters distinguished by font. The lists were randomized and each was broken into 4 blocks of 33 sentences. In addition, a block of 20 practice trials preceded the experimental blocks.

Procedure and Apparatus. Participants were first acquainted with the equipment and then given a block of 20 practice sentences to read, including all experimental conditions, randomly presented. Participants were instructed to "read for comprehension. Sometimes extra, distracting words occur in the sentences. These words are cued by change in color from black to red or a change in font from roman to italics. You should ignore these words and focus on understanding the sentence. A question will follow each sentence and you should answer the question out loud." Each participant was assigned randomly to 1 of 12 stimulus lists. Then 4 blocks of 33 sentences were presented; order of the blocks was counter-balanced across participants. Each block contained sentences from each experimental condition, randomly presented.

Each trial consisted of a fixation point at the left margin of a blank screen for 500 msec followed automatically by the presentation of a sentence. The participants controlled presentation duration by pressing the mouse when they had completed reading the sentence. Participants sat in an adjustable chair with a head rest. They wore reading glasses if they normally did so. The chair could be raised or lowered to accommodate to bi- or tri-focal lens. The participants also wore a visor with a small magnetic sensor attached. The sensor was interfaced with a headtracker to monitor head movements. The sentences were presented on a 17 in flat panel computer screen at a viewing distance of 16 in. The fixation point and stimulus items were presented in white (125.5 lux) on a black background (0.03 lux) to maximize pupil size. Text was presented in Arial typeface with a mean size for individual letters of 0.57°. The participants held a computer mouse in their preferred hand which was used to control sentence presentation.

An Applied Sciences Laboratories eye tracker (Model 504) with a magnetic headtracker was used to record eye movements. Eye movements were sampled 60 times per sec with an accuracy of 0.5° visual angle. This translates to approximately 0.5 to 1 cm accuracy at 16 in. The headtracker noted displacements of the sensor attached to the readers' visor relative to a base unit and corrected the record of eye movements for head movements. Head movements were sampled 100 times per sec with an accuracy of 0.03° at 12 in. Stimuli were presented using GazeTracker software (Lankford, 2000) which also analyzed the eye movement data. The eyetracker was calibrated at the start of each session and between blocks for each participant. One microcomputer controlled the eye tracker; it was interfaced with a second computer running the GazeTracker software for presentation and analysis.

Eye movement parameters were analyzed for the following critical words in each sentence: (1) The target word, (2) the distracter, if present, (3) 1 - 3 words preceding the target (and distracter if present) as the pre-target flanker, and (4) 1 -3 words following the target as a post-target flanker. Target words were analyzed to determine if the readers attempted to integrate the distracter with the sentence, which was expected to result in an increase in fixation times for the target words. The flankers were analyzed to determine if the presence of the distracter disrupted normal reading strategy by affecting fixations to these words. In many cases, these flankers were short function words, e.g., *of, a*, *the*, which are often not fixated by skilled readers (Rayner & Duffy, 1988); in these cases, the flanker was extended to include a content word.

Four measures were computed for each critical word: the probability the word was fixated at least once, the duration of the first pass fixation to the word, the total duration of all fixations to a word, and first-pass regressions leftward to a previous word calculated as the percentage of the total number of leftward regressions for each sentence. First pass fixation duration is the sum of all fixations to a region beginning with the initial fixation to a word and ending with either the first fixation leftward to a previous word or rightward to a successive word. Total fixation duration included all first-pass fixations as well as any fixations resulting from regressions to the word or subsequent re-fixation after a leftward or rightward fixation to another word. Fixations were defined as a minimum of two successive eye positions occurring with a fixation diameter of 30 pixels. Finally, total sentence reading time and overall accuracy in answering the probe questions were determined.

Data from 4% of the experimental sentences was lost due to eye blinks, large head movements, or other eye tracking failures. In addition, in order to assure that participants were engaged in the reading task, only trials on which the probe question was correctly answered were included in the analysis of the fixation data. This eliminated more trials for older adults (8%) than for young adults (3%), but comprehension accuracy did not did not interact with age and presence/absence of distracters (see the analysis of comprehension data below). Thus we did not drop data differentially from the experimental conditions for the two age groups.

At the conclusion of the reading experiment, participants were administered a word recognition test. The words included 24 distracters, 12 (6 related, 6 unrelated to the sentence) originally cued by a change of color and 12 (6 related, 6 unrelated to the sentence) by a change in font, 24 targets (12 high predictability, 12 low predictability), 24 fillers (content words selected from the filler sentences), and 24 foils (content words that did not appear in any of the experimental sentences or filler sentences). The words were randomly ordered for each participant. Participants first decided if they recognized the word and then gave a confidence rating using a 3-point scale with 1 = only guessing, 2 = somewhat confident, 3 = very confident.

Results

Descriptions of analyses and findings are organized according to *a priori* predictions based on inhibitory deficit theory.

Total reading time will be longer for older than for younger adults. Sentence reading times were analyzed with a 2 age group x 3 distracter type (none, font, color) x 3 distracter relatedness (no distracter, related distracter, unrelated distracter) x 2 target predictability (high, low) ANOVA. The main effect of age was significant, F (1, 46) = 4.68, $p < .02$, $\eta^2 = .14$. Older adults read the sentences more slowly (M = 6751 ms, SD = 407) than young adults (M = 5646 ms, SD = 411). There was also a significant effect of distracter type, F (1, 46) = 33.13, $p < .01$, $\eta^2 = .60$. Sentences without distracters were read more rapidly (M = 5563 ms, SD = 306) than sentences with distracters distinguished by color (M = 6048 ms, SD = 265), and sentences with distracters distinguished by color were read more rapidly than those with distracters distinguished by font (M = 6985 ms, SD = 338). The age group by distracter type interaction was not significant, F (1, 46) = 0.41, $p = .53$, $\eta^2 = .41$. All other effects and interactions were not significant in this analysis. The absence of any interactions with age groups is inconsistent with inhibitory deficit theory, and does not replicate the findings of Connelly et al. (1991). However, as we have argued above, total reading time is not the best index of distracter processing. Subsequent analyses more closely examine processing times for subsets of the presented text.

Older adults will be more likely to fixate distracters and to spend more time fixating distracters than young adults. This age difference will be more pronounced for the distracters presented in italics than for those presented in color. The probability of at least one fixation to the distracters, first pass fixation times to the distracters, and total fixation times to the distracters were analyzed with separate 2 (age group) x 2 (distracter type) x 2 (distracter relatedness) x 2 (target predictability) ANOVAs. In each analysis, only the main effect of distracter type was significant. In the case of probability of fixation, the probability of fixating distracters that differed in font (.98, SD = 0.02) was greater than the probability of fixating a distracter that differed in color (.75, SD = 0.04), F (1, 46) = 43.26, $p < .01$, $\eta^2 = .49$. The age group by distracter type interaction, F (1, 46) < .01, $p = .95$, $\eta^2 < .01$, was nonsignificant. These findings indicate that both young and old adults were more likely to fixate distracters that differed in font than those that differed in color.

More diagnostic for an age-related inhibitory deficit, however, is the amount of time spent fixating the distracting text. Regarding first pass fixation duration, our findings indicate that the participants could use color (M = 291 ms, SD = 20) to terminate first pass fixations to the distracters more rapidly than they could use font (M = 475 ms, SD = 19). This difference was statistically significant, F (1, 46) = 47.72, $p < .01$, $\eta^2 = .51$. Total fixation durations for the distracters followed a similar pattern; the main effect of distracter type, F (1, 46) = 147.82, $p < .01$, $\eta^2 = .76$, was significant. Total fixation times were shorter for distracters that differed in color from target text (M = 1300 ms, SD = 121) than those that differed in font (M = 1795 ms, SD = 148). The age group by distracter type interaction for first pass fixations F (1, 46) = .39, p = .54, η^2 = .09, and total fixations, F (1, 46) = .314, p = .578, η^2 = .09, were non significant, again providing no evidence for an age-related inhibitory deficit.

Older adults will make more leftward regressions to distracters after their first pass fixation. A 2 (age group) x 2 (distracter type) x 2 (distracter relatedness) x 2 (target predictability) ANOVA was carried out on percent of all regressions that were directed to distracter text. The main effects of distracter type, F (1, 46) = 233.57, p < .01, η^2 = .84, and distracter relatedness, F (1, 46) = 8.19, p < .01, η^2 = .15, were significant. Participants made fewer regressions to distracters distinguished by color (M = 10%, SD = 1) than to distracters distinguished by font (M = 24%, SD = 1). The participants also made fewer regressions to the distracters when the distracters were unrelated to the sentence (M = 16%, SD = 1) than when they were semantically related to the sentence (M = 19%, SD = 2). The age group by distracter type interaction, F (1, 46) = 1.50, p = .22, η^2 = .22, and the age group by distracter relatedness interaction, F (1, 46) = .56, p = .57, η^2 = .14, were nonsignificant. All other main effects and interactions were nonsignificant in this analysis. The absence of any age effects again provides no support for an age-related inhibitory deficit.

The presence of distracters will disrupt sentence text processing among older adults. To test this hypothesis, visual processing of pre-target flankers, target words, and post-target flankers (see Table 2) were examined with a series of 2 age group x 3 distracter type (none, font, color) x distracter relatedness (none, related, unrelated) x 2 target (high, low predictability) ANOVAs on first pass fixation times, regressions, and total fixation times. For pre-target flanker text, there were no significant effects or interactions for first pass fixation times, indicating that properties of the distracters or targets did not affect reading the initial part of the sentence. However, the analysis of percent regressions revealed a significant interaction of distracter type and distracter relatedness, F (2, 45) = 12.09, p < .01, η^2 = .37. Regressions to the pre-target flankers were more frequent when there was a related distracter distinguished by font (M = 24% of all regressions, SD = 6) than in the other conditions (M = 16%, SD = 6). This pattern of results indicates that when distracter text is difficult to ignore by virtue of being hard to detect or related to the meaning of the sentence, the visual processing of the sentence is altered such that target text is more frequently re-read. The distracter type by distracter relatedness interaction did not, however, vary with age, F (2, 45) = .96, p < .33, η^2 = .16.

Analysis of total fixation times to pre-target flankers showed main effects for distracter type, F (2, 45) = 31.08, p < .01, η^2 = .58, and relatedness, F (1, 46) = 6.02, p < .05, η^2 = .12. Total fixation times to the pre-target flankers were longer when the distracters were distinguished by font (M = 1687 ms, SD = 143), than when they were distinguished by color (M = 1473 ms, SD = 130) or when there was no distracter (M = 1468 ms, SD = 137). Total fixation times to the pre-target flankers were longer when the distracters were semantically related to the sentence (M = 1611, SD = 143) than when the distracters were unrelated (M = 1543, SD = 131). Thus the physical and semantic characteristics of the distracter did change the pattern of eye movements to the sentence text, but there were no significant age group differences in the pattern of fixations to the pre-target flankers.

We next examined first pass fixation times, regressions, and total fixation times to the target word in each sentence, using a series of 2 age group x 3 distracter type x 3 distracter relatedness x 2 target predictability ANOVAs. Beginning with first pass fixation times, the analysis revealed a main effect for distracter type, F (2, 45) = 5.09, p < .01, η^2 = .18; targets were fixated longer when the distracters were distinguished by font (*M* = 405 ms, *SD* = 32) than in the other two conditions that did not differ in target fixation time (M = 345 ms, SD = 34). Targets were also fixated longer when the distracters were semantically related to the sentence (*M* = 381 ms, *SD* = 28) than when the distracters were unrelated (*M* = 352 ms, *SD* = 28). In addition, there was a significant interaction between age group and predictability, F (1, 46) = 14.40, $p < .01$, $\eta^2 = .24$. This interaction is depicted in Figure 1. Young adults' fixations to low predictability targets (*M* = 384 ms, *SD* = 40) were longer than their fixations to high predictability targets (*M* = 307, *SD* = 38) whereas older adults' fixation durations did not vary with target predictability (*M* = 391, *SD* = 40). Thus older adults apparently did not take advantage of the sentence context to reduce processing of the predictable target words.

Regressions to the target showed a similar pattern: a significant main effect of distracter type, F (2, 45) = 17.93, $p < .01$, $\eta^2 = .44$, indicated that there were more regressions to the targets when the distracters were distinguished by font (*M*= 34% of total regressions, *SD* = 1) than in the other two conditions (*M* = 26%, *SD* = 1). In addition, the age group by target predictability interaction was significant, F (1, 46) = 8.61, $p < .01$, $\eta^2 = .28$; it is depicted in Figure 2. Young adults made fewer regressions to high predictability targets (*M* = 20% of total regressions, *SD* = 2) than to low predictability targets (*M* = 25%, *SD* = 12) whereas older adults' regressions did not vary with target predictability (*M* = 25%, *SD* = 10).

The analysis of total fixation times also revealed a main effect for distracter type, F (2, 45) = 13.00, $p < .01$, $\eta^2 = .37$. Targets were fixated longer when the distracters were distinguished by font (*M* = 1498 ms, *SD* = 190) compared to the other two conditions (*M* = 1388, *SD* = 197). The main effect for age group, F (1, 46) = 4.65, $p < .05$, $\eta^2 = .10$, and the age group by target predictability interaction, F (1, 46) = 4.64, $p < .05$, $\eta^2 = .17$, were also significant. The interaction is shown in Figure 3. Young adults' total fixation times to low predictability targets (*M* = 1506, *SD* = 192) were longer than their total fixation times to high predictability targets (*M* = 1097, *SD* = 197) whereas older adults' total fixation times did not vary with target predictability (*M* = 1639, *SD* = 190).

Eye movements involving post-target flanker text (see Table 2) were also examined with a series of 2 age group x 2 distracter type x 2 distracter relatedness x 2 target predictability ANOVAs on first pass fixation times, regressions, and total fixation times. There were no significant effects in the analysis of first pass fixations or of regressions to the post-target flanker. For total fixation time, only the effect of target predictability reached significance, F (1, 46) = 10.25, $p < .02$, $\eta^2 = .18$. Flankers following high predictability targets were fixated for less time (*M* = 584 ms, *SD* = 90) than those following low predictability targets (*M* = 504 ms, *SD* = 92). There were no significant age differences in fixation patterns for post-target flankers.

Older adults will have less good comprehension performance on probe questions than young adults. The percentage of probe questions answered correctly was analyzed with a 2 age group x 3 distracter type x 2 distracter relatedness x 2 target predictability ANOVA. The main effect of age was significant, F (1, 46) = 11.66, $p < .01$. Older adults (*M* = 92.3%, *SD* = 1%) answered fewer questions correctly than young adults (*M* = 97.4%, *SD* = 3%). There was also a significant effect of distracter type, F (1, 46) = 27.19, $p < .01$. Probe questions for sentences without distracters were more likely to be answered correctly (*M* = 98%, *SD* = 1%) than questions for sentences with distracters distinguished by color (*M* = 94.5%, *SD* = 3%), and probes sentences with distracters distinguished by color were more likely to be answered correctly than those with distracters distinguished by font (*M* = 87.2%, *SD* = 3%).

Age did not interact with distracter type, F (1, 46) = .08, p =.79, η^2 = .06, indicating that young and older adults' comprehension was not differentially affected by the presence of distracting text.

Older adults will be more likely to recognize distracter text in a test of recognition memory than young adults. Table 3 summarizes recognition rates for young and older adults for the foils, fillers, targets, and distracters. Only fillers, targets, and distracters actually fixated by the participants were included in the analysis. One-way ANOVAs were used to compare young and older adults' recognition rates and confidence ratings for the foils and filler items. Young adults and older adults falsely recognized few foils, M = 3.4% (SD = 1.2), F(1,46) < 1.0, and they were equally confident in their responses, M = 2.3 (SD = .3), F(1,46) < 1.0. Young correctly recognized more fillers (M = 29.7%, SD = 3.1) than older adults (M = 22.0 %, SD = 6.8), F(1, 46) = 130.05, p = .01, η^2 = .63 , although they were equally confident, M = 2.5 (SD = .4), F(1, 46) < 1.0.

ANOVAs with age group, distracter type, distracter relatedness, and target predictability as factors were used to compare recognition rates and confidence ratings for the targets and distracters. Young (M = 53.4%, SD = 8.2) and older adults (M = 41.5%, SD = 7.3) differed in their memory for targets, F (1, 46) = 140.22, p < .01, η^2 = .75, although they were equally confident, F(1,46) < 1.0. Neither distracter type or relatedness or target predictability had any effect on target recognition rates or confidence ratings. Regarding memory for distracters, young (M = 19.0%, SD = 5.2) and older adults (M = 8.4%, SD = 5.3) again differed, F (1, 46) = 234.12, p < .01, η^2 = .84, although they were equally confident, F(1,46) < 1.0. Contrary to the prediction of inhibitory deficit theory, but consistent with the data of Dywan and Murphy (1995), young adults recognized more distracters than did older adults. The distracter type x relatedness interaction was also significant, F(1, 46) = 11.26, p < .01, η^2 = .21. Semantically unrelated distracters distinguished by color (M = 13.8%, SD = 4.5) were correctly recognized less often than other types of distracters (M = 16.7, SD = 3.8) although confidence ratings did not vary, F(1,46) < 1.0.

Discussion

The present experiment was undertaken in an attempt to resolve contradictory findings in the literature on age differences in reading with distraction. Consistent with inhibitory deficit theory, older adults have been shown to be slower and less good at comprehending text that included distracting information than young adults (Carlson et al., 1996; Connelly et al, 1991). However, young adults have been reported to be better at recognizing the to-be-ignored distracting text (Dwyan & Murphy, 1996; Multhaup et al, 1998), a finding which is not consistent with models of inhibitory function proposing that young adults use inhibitory processes to avoid processing distracters.

In our studies, we measured eye movements during reading in an effort to examine the immediate, on-line processing of text and distracters by both young and old adults. We presented single sentences with one-word distracters that were distinguished from target text either by text color or text font. In addition, the distracters were either related or unrelated to the meaning of the sentence. We replicated earlier work using reading time, comprehension, and recognition memory measures: older adults took longer to read the sentences with distracters than did young adults and older adults had poorer comprehension of the sentences. Connelly et al. (1991) interpreted this pattern of results as suggesting that distracting text may "trigger greater attentiveness for older adults than for younger adults" (p. 539). However, if that were the case, older adults should also show longer fixation durations for distracters. Contrary to this expectation based on inhibitory deficit theory, our data show that both young and old adults looked at the distracting text to the same extent; we observed no age differences in the probability of fixating the distracter text or in the amount of time spent fixating the distracter text. This pattern of results indicates that there are no age-related differences in the inhibitory control of on-line processing, at least as indexed by eye movements, and provides little support for inhibitory deficit theory.

Specific properties of the distracters did affect visual processing for both young and old adults: distracters that were distinguished by color were less likely to be fixated, fixated for shorter time, and triggered fewer regressions than distracters distinguished by font. Thus less processing was allocated to text easily identified as distracter. In contrast, sentences with distracters that were related to the meaning of the sentence produced more regressions and longer total fixation times to pre-target flankers, distracters, and target words, perhaps reflecting greater efforts at integrating distracting text with the sentence. Most striking is the absence of interactions between the manipulations of the visual salience of the distracters and their semantic relatedness to the sentence. This suggests that two separate decision-stages were involved in terminating processing, one based on visual salience and one based on semantic relatedness.

Regarding visual processing of other components of the sentence text, older adults' fixation patterns closely mirrored young adults' with one exception. Older adults' first pass fixations and total fixation times to target words did not vary with the predictability of the targets whereas young adults' did: Young adults spent less time fixating predictable targets than unpredictable targets, suggesting young adults quickly utilize semantic and pragmatic information to minimize processing of highly predictable words. Older adults did not. A similar finding was reported by Mitzner, Radel, Filion, & Kemper (2001). Because older adults read the sentences somewhat more slowly than young adults, it may be that older adults spent more time during their reading trying to integrate the distracter with the meaning of the sentence, which would diluted the effect of the semantic context, making it a less powerful predictor of the target word.

Although both young and old adults processed distracter text, older adults may have made greater attempts to integrate sentence and distracter text, leading to poorer comprehension. This is consistent with Dywan and Murphy's (1996) suggestion that old adults are "less likely than younger adults to distinguish between sources of familiarity" (p. 204). The finding that young adults in the present study had superior recognition memory for the distracters compared to older adults is also consistent with the findings of Dywan and Murphy (1996). They suggested that young and old adults both process and keep active in working memory target and distracter text. Because young adults are better able to distinguish target and distracter information, comprehension performance may be unaffected by the distracter text while at the same time their better memory ability leads to more frequent recognition of distracter items. Consistent with this notion is the finding in the present study that young adults' also had superior recognition memory for the targets and words from the filler sentences, implying an overall memory advantage for young adults.

In summary, by tracking the eye movements of young and older adults reading sentences with interpolated distracters, we find little support for Inhibitory Deficit theory. Older adults were no more likely to fixate distracters than young adults, older adults' fixations to distracters, both first pass and total fixations, were no longer than young adults', and older adults were no more likely to make regressions to the distracters than young adults. Thus our findings do not support the conclusions of earlier studies that accounted for age differences in reading performance in terms of an age-related deficit in inhibition. We suggest that the more fine-grained analysis allowed by eye tracking methodology gives a more accurate account of visual information processing among young and old adults than does a single reading time measure. However, there are other methodological differences between our study and those of Connelly et al. and Dywan and Murphy. For example, our materials differed from those used by Connelly et al. and Dywan and Murphy. They both used paragraph texts, with distracting text ranging in length from 1 – 3 words. They also repeated the same distracter text several times throughout a single target paragraph. In contrast, single sentences with single-word distracters were used as stimuli in the present study. Although we can not say for sure that these differences are critical to the differences in our findings, the clear and repeated absence of age differences in our study suggest that this is not the case. This is not to say that older adults do not experience changes in inhibitory function, but rather that the reading in distraction studies do not provide support for this hypothesis.

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Table 1

Characteristics of the participants.

	Young	Older	*F*(1,46)	*p* <
Age	19.8 (1.1)	75.3 (5.9)		
Reading leisure (hrs/wk)	4.8 (5.1)	13.9 (8.3)	21.456	.001
Reading work/school (hrs/wk)	10.0 (9.1)	2.1 (4.4)	14.821	.001
Vocabulary	30.9 (3.2)	34.6 (3.8)	13.806	.001
Digits forward	8.9 (1.7)	6.7 (1.3)	20.262	.001
Digits backward	7.5 (2.1)	5.6 (1.2)	12.955	.001
Reading Span	3.8 (1.2)	2.9 (0.7)	20.407	.001
Probe Questions (% correct)	97.4 (1.1)	92.3 (1.2)	11.666	.001
Sentence Reading Time (sec)	5.7 (1.9)	6.8 (2.1)	3.683	.061

Table 2

Example sentence materials. Pre- and post-target flankers are underlined and the position of the distracter (if any) and the target word are indicated.

Sentence:

To keep animals out of the garden, he *put up a* (distracter) TARGET to block it off.

Related distracter	protects
Unrelated distracter	sweeps
High predictability target	fence
Low predictability target	hedge

Probe Question: How did he keep the animals out of the garden?

Table 3

Recognition accuracy and confidence ratings. The percentage of items judged to be OLD is given (with Standard Deviations in parentheses) along with average confidence rating where a rating of 1 = only guessing and a rating of 3 = very confident.

	p(OLD)		Confidence Rating	
	Young Adults	Older Adults	Young Adults	Older Adults
Foils	2.5 (2.2)	4.2 (2.3)	2.3 (0.3)	2.1 (0.4)
Fillers	29.7 (3.4)	22.0 (2.8)	2.5 (0.4)	2.4 (0.4)
Targets	53.4 (7.9)	41.4 (7.3)	2.5 (0.4)	2.4 (0.3)
Distracters	19.0 (5.2)	8.4 (5.4)	1.8 (0.3)	1.8 (0.3)

Figure Captions

Figure 1. First pass fixations (and *SE*s) for young and older adults to target words varying in predictability.

Figure 2. The percentage of total regressions (and *SE*s) which were made to the target words varying in predictability.

Figure 3. Total fixation durations (and *SE*s) for young and older adults to target words varying in predictability.

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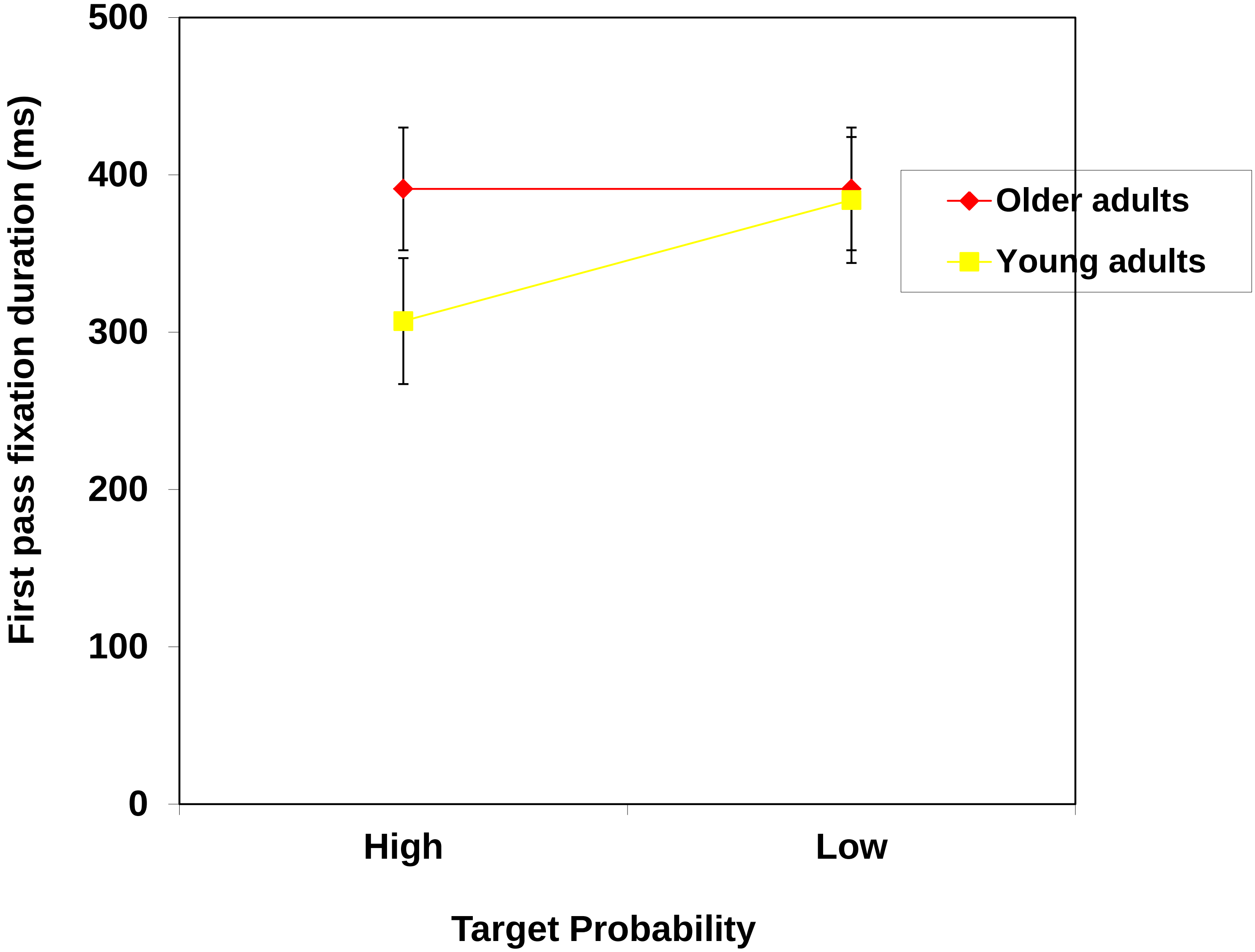
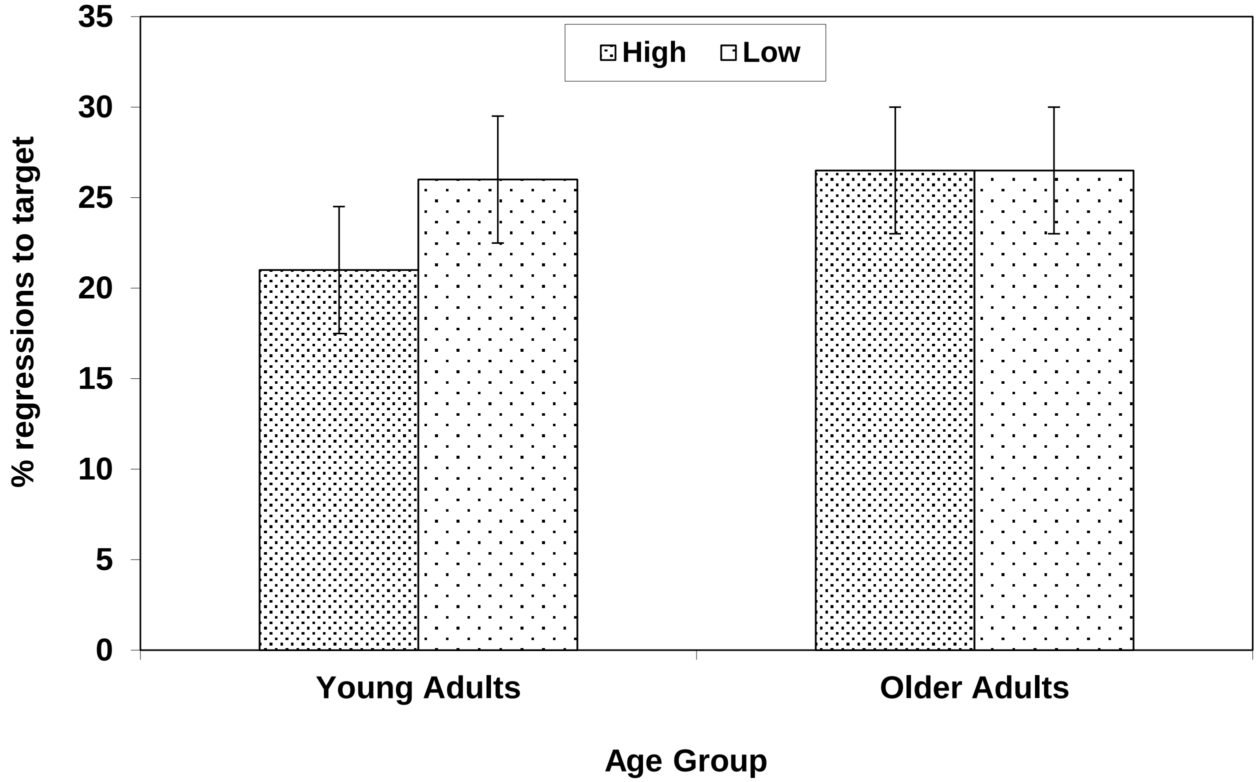
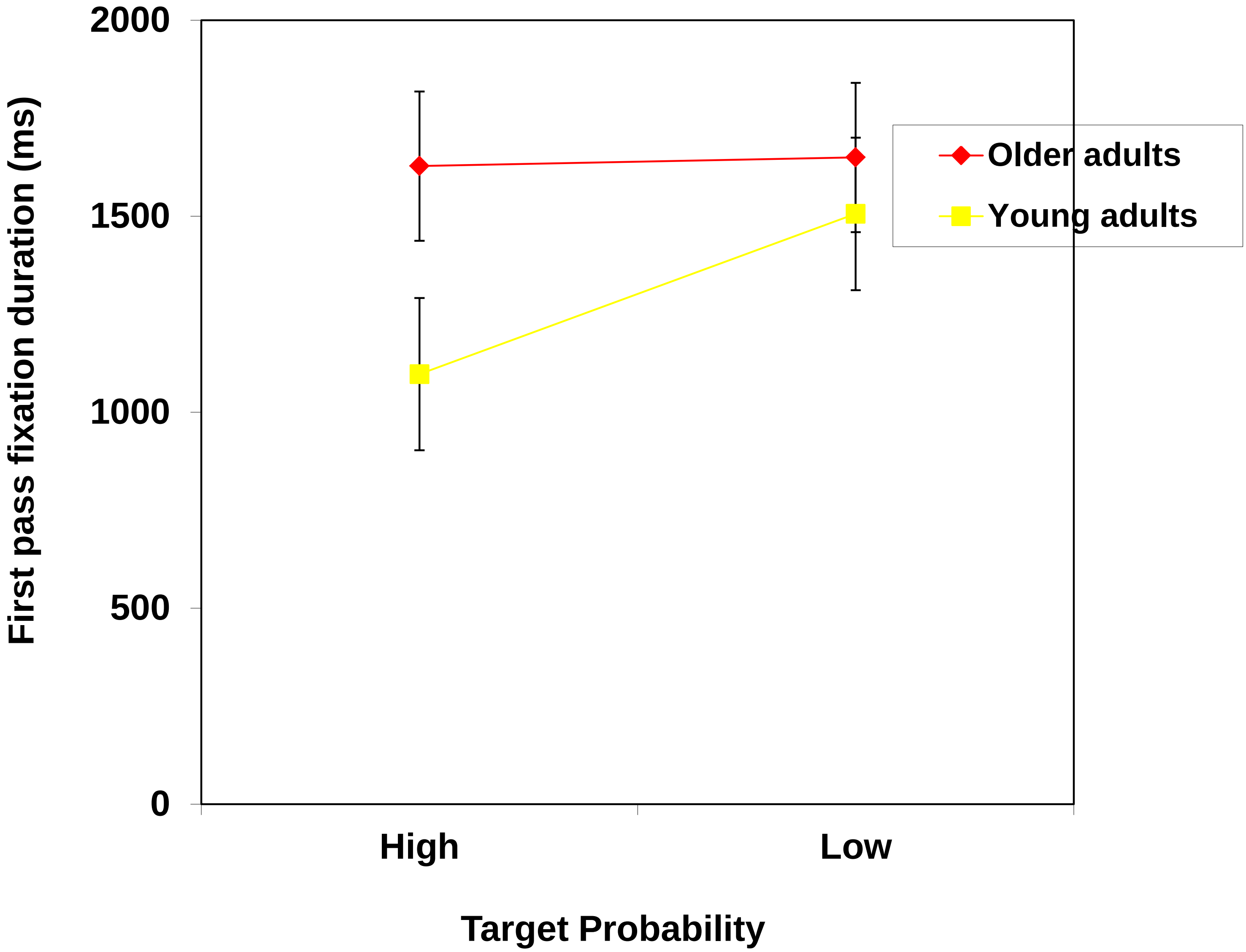



35
30
25
20
15
10
5
0
% regressions to target
High
Low
Young Adults
Older Adults
Age Group


2000
1500
1000
500
0
First pass fixation duration (ms)
Older adults
Young adults
High
Low
Target Probability