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Learning to Ignore Distracters

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Abstract

Eyetracking has indicated that older and young adults process distracters similarly when reading single sentences. The present study extended this approach by presenting short paragraphs sentence by sentence. Eyetracking measures included reading times per word, and the duration of the first fixation and total fixations to the distracters and target words. Comprehension was tested following each paragraph and recognition of distracters and target words was assessed. The results indicated that young adults were able to learn to ignore the distracters as they read through the paragraphs whereas older adults were less successful at learning to ignore the distracters.

Keywords

Reading; Eyetracking; Older Adults; Distraction; Inhibition

Age-related inhibitory deficits continue to be a focus of investigation as researchers work to identify the circumstances under which such deficits are observed by, e.g., tracking ERP responses to simultaneous targets and distracters (de Fockert, Ramchurn, van Velzen, Bergstrom, & Bunce, 2009) or using EEG to monitor the time course of inhibitory processes (Gazzaley, Clapp, Kelley, McEvoy, Knight, & D'Esposito, 2008). In the present line of work, Kemper and McDowd (2006) used eyetracking to test predictions from the Inhibitory Deficit Theory (IDT) (Hasher & Zacks, 1988; Connelly, Hasher & Zacks, 1991), namely that young, but not older adults, are able to ignore distracters while reading. If so, young adults should make fewer and shorter fixations to distracters than older adults. Kemper and McDowd presented readers with single sentences; distracters, if present, were distinguished by color or by a change in font and varied in their semantic relatedness to the sentence. They found that both young and older adults could use color to rapidly terminate fixations to distracters and to reduce the number of regressive fixations to distracters. Most critically, fixation patterns of young and older adults to distracters were similar, providing little support for IDT. The present study extended this investigation by using a format more consistent with the original Connelly et al. (1991) procedure in which multi-sentence paragraphs were presented and a set of distracters was repeated throughout the paragraph. Braver and colleagues (e.g., Braver et al., 2001; Rush, Barch & Braver, 2006) have postulated a theory of reduced context processing and maintenance in aging, based on data showing that older adults are less able to take advantage of context to improve performance

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than are young adults. Hence, Connelly et al.'s multi-sentence paragraphs and repeated distracters may have allowed young adults to learn to ignore the distracters by using contextual information. Thus, context theory and IDT would predict that young adults will spend less and less time attempting to integrate distracters into each sentence as they read through the paragraph sentence by sentence whereas older adults will not benefit from the contextual cues and continue to have difficulty distinguishing distracters from relevant words. We compared young and older adults' reading times, the duration of the initial fixation, and the duration of all fixations to selected target words and to distracters as a function of sentence serial order. In addition, we included neuropsychological measures of processing speed, working memory, and inhibitory processes in an effort to best characterize any age-related deficits we might observe.

Method

Participants

Forty-five older adults and 38 young adults participated. The older adults were all community dwelling adults recruited from prior research participant databases. The young adults were all college students recruited on campus. All participants were monolingual English speakers. All received an honorarium for their participation.

Data from 7 older adults and 1 young adult were lost due to eye tracking failures. To be included in the data analysis, participants had to score above 80% correct on the comprehension questions presented after the paragraphs. This criterion was used to eliminate individuals with general reading problems. Based on this criterion, 5 older adults and 3 young adults were excluded, resulting in data from 33 older adults (*M* = 75.2 years, *SD* = 4.7) and 34 (*M* = 75.2 years, *SD* = 4.7) young adults. These individuals all scored at least 1 SD below their age group mean on the vocabulary and reading span tests.

Demographic Information and Neuropsychological Test Performance

Based on 1-way ANOVAs, older adults had more years of education (*M* = 18.1 years, *SD* = 3.1) and had higher scores (*M* = 35.2, *SD* = 2.0) on a vocabulary test (Shipley, 1941) than the young adults (*M* = 14.5 years, *SD* = 2.2; *M* = 31.4, *SD* = 3.4) whereas young adults outperformed the older adults on the Stroop 45 s baseline test reading blocks of colored XXXs (M_Y = 84.5 blocks, *SD* = 14.1; M_O = 71.6 blocks, *SD* = 12.8), Stroop color word test (M_Y = 60.4 words, *SD* = 11.5; M_O = 39.0 words, *SD* = 9.4), and the Daneman and Carpenter (1980) reading span test (M_Y = 3.3 sentences, *SD* = 0.6; M_O = 2.9 sentences, *SD* = 0.7). The young and older adults had similar forward digit spans (M_Y = 8.8 digits, *SD* = 2.2; M_O = 8.4, *SD* = 2.3) and backward digit spans (M_Y = 7.7 digits, *SD* = 2.2; M_O = 6.7, *SD* = 1.6), and scores on the Cognitive Failures Questionnaire (M_Y = 62.0, *SD* = 10.6; M_O = 60.0, *SD* = 8.9) (Broadbent, Cooper, FitzGerald, & Parkes, 1982). A working memory composite measure was computed for each participant by averaging their scores on the two digit span tests and the reading span test. Performance on the Stroop XXX condition was used a measure of processing speed; a Stroop interference score was also computed for each participant as: Interference = (blocks of XXX – blocks of color names) / blocks of XXX). An alpha level of 0.5 was set for these and all subsequent statistical tests.

Materials

There were 8 short paragraphs with 2 versions differing in the inclusion of distracters. Each paragraph was composed of 9 sentences (*M* = 127 words; *SD* = 20), presented one sentence at a time. The sentences were presented in white italicized text (20 point, Arial font) on a solid black background. Each sentence was between 1 and 3 lines long.

In the distracter version, each sentence contained 1 to 4 distracters. Within a paragraph, a set of 11 to 12 distracters was repeated throughout the paragraph with each individual distracter repeated 2 or 3 times. Distracters were not used in other paragraphs. The distracters were randomly placed in the sentences, semantically and syntactically unrelated to the paragraph, and visually distinguished from the italicized text by a shift to Roman font. Consistent formatting was used with the 2 versions such that the number of lines and line breaks were identical for each sentence in each paragraph.

To facilitate the eyetracking analysis, a target was selected from each sentence so that in the paragraphs with distracters, the target preceded a distracter which was also used in the eyetracking analysis. Targets and distracters were similar in terms of word frequency (M_T = 18.1 per million; M_D = 17.6 per million, $p > .50$) (New, Brysbaert, Veronis, & Pallier, 2007) and length in characters (M_T = 6.3 ; M_D = 5.8, $p > .50$). Table 1 provides 2 versions of a paragraph and indicated which targets and distracters were chosen for analysis. There were 3 comprehension questions following each paragraph: 2 factual comprehension questions asking who, what, or where, and 1 inferential comprehension question asking why or how. Following the reading task, participants completed a word recognition task that included targets, distracters, and foils, words that had not appeared in any of the paragraphs.

Apparatus

An Applied Sciences Laboratories D6000 eyetracker (Bedford, MA) with remote optics was used to record eye movements. Stimulus presentation and the eye movement analysis were controlled using GazeTracker software (Lankford, 2000). The eye tracker was calibrated at the start of the session and after every second paragraph. The participants were seated in an adjustable chair that could be lowered or raised to accommodate the height and corrective glasses of the participant. Participants wore reading glasses if needed and were free to shift about in the chair or vary their head position. The paragraphs were presented on a flat panel computer screen at a viewing distance of 16 inches. The stimuli were presented in white font on a black screen to maximize pupil size. The keyboard placed on the participant's lap was used to control the timing of sentence presentation.

Procedure

Participants completed acuity and contrast sensitivity tests before beginning the experiment to ensure that they could read the material presented on the computer screen. A block of 4 paragraphs without distracters preceded a second block of 4 paragraphs with distracters. Each block started with three practice sentences and a comprehension question to orient participants to the task. Paragraphs were assigned to blocks and counterbalanced across participants.

Following Connelly, Hasher, and Zacks (1991), the participants were instructed to read each sentence out loud before advancing to the next sentence by pressing the spacebar on the keyboard. They were instructed to read each question out loud and answer out loud. They were given explicit instruction that there would be distracters presented in a different font and that they should not read the distracters aloud but try to ignore them.

Fixations less than 100 ms in duration were excluded from the analysis; data from approximately 6% of the sentences (3% for young adults, 9 % for older adults) was lost due to this criterion or to a loss of tracking calibration. Five dependent eye movement measures were collected for analysis: reading time, the duration of the first and total fixations to targets, and the duration of the first and total fixations to distracters. Reading time was the average time in seconds per word, adjusted for the number of distracters, if any. The duration of the first fixation was the duration of the first look to either the target or distracter; it is a measure of initial processing. The duration of total fixations was the duration of all fixations to the target or distracter including the first fixation and any later re-fixations or regressions after a fixation to a different word. The duration of total fixations is a measure of overall processing of the targets or distracters reflecting the cumulative effects of syntactic, semantic, and pragmatic processing.

Results

Multilevel modeling was used to investigate the impact of age (young versus older adults), distracters (no distracters, with distracters), and serial order of the sentences (1 to 9) on the five dependent measures. A 2-level model was built for each dependent measure with sentences (level 1) nested within individuals (level 2). This method allows for estimation of the effects due to the presence of distracters or of the serial order of sentences on the dependent measures as well as estimates of the effects of age group or individual differences in working memory, processing speed, vocabulary, and inhibition (Blozis & Traxler, 2007; Quene & ven den Bergh, 2004).

Model development for the reading time and target fixations preceded in a series of steps: fixed effects for the presence of distracters and age were entered first, followed by their interaction, and then a random effect of serial order was added along with its interactions with age group and distraction. Model development for the distracter fixations was similar with age group entered first, followed by serial order and the age group by serial order interaction. Models for target and distracter fixations also included sentence reading time and the age group by reading time interaction. Additional models tested whether the effects of distracters and serial order were moderated by individual differences working memory, processing speed, vocabulary, and inhibition by including these measures as a level-2 (or person-level) predictors along with age group, reading time, and their interactions. All significant effects at $\alpha = .05$ are reported. In general, positive estimates (β) indicate longer reading times or longer fixation times.

Reading Time

When distracters were present, all participants read more slowly, as indicated by the significant estimate for distracters, $\beta = 0.263$, $SE = .010$, $p < 0.001$. Older adults read more slowly than young adults, $\beta = 0.079$, $SE = .022$, $p < .0001$, and distracters differentially slowed older adults, indicated by the significant age by distracter interaction, $\beta = 0.127$, $SE = .009$, $p < .0001$. In addition, the serial order of the sentences affected reading time, $\tau = 0.002$, $SE = .00051$, $p < .001$, such that reading time decreased as the participants read through the paragraphs sentence by sentence. However, this decrease in reading time only occurred when there were distracters, as indicated by the distracter by serial order interaction, $\beta = -0.140$, $SE = .002$, $p < .0001$. Further, the decrease in reading time with serial order was attenuated for older adults, as indicated by the significant negative estimate for the age by serial order interaction, $\beta = -.006$, $SE = .002$, $p < .0001$. See Figure 1.

A series of models tested whether individual differences in working memory, processing speed, vocabulary, and inhibition moderated the effects of distraction and serial order by including them as additional person-level predictors of reading speed along with their interactions with age group. Readers with better working memory had an slight advantage in the reading with distraction condition, as indicated by the significant distracter by working memory interaction, $\beta = -.023$, $SE = .004$, $p < .0001$; readers who were faster on the Stroop XXX condition had an very slight advantage, as indicated by the significant distracter by processing speed interaction, $\beta = -.003$, $SE < .001$, $p < .0001$; readers who had better vocabularies had an slight disadvantage, as indicated by the significant distracter by vocabulary interaction, $\beta = .003$, $SE = .001$, $p < .039$. However, readers with better inhibition had a large advantage, as indicated by the significant distracter by inhibition interaction, $\beta = -.386$, *SE* = .035, $p < .0001$; indeed, for readers with inhibition scores + 1 SD above their age group mean, there was no effect of distracters on reading time.

Duration of Fixations to Targets

In general, there were few significant effects in the analysis of the duration of the first fixation to the targets but greater cumulative effects in the analysis of the duration of total fixations. First fixations to targets were longer for older adults than for young adults, as indicated by the main effect of age, $\beta = 0.049$, *SE* = .013, $p < 0.001$; first target fixations also increased with sentence reading time, $\beta = 0.021$, *SE* = .004, $p < 0.01$. The duration of total fixations to targets was also longer for older adults, $\beta = 0.133$, *SE* = .042, $p < 0.001$; total target fixations also increased with sentence reading time, $\beta = 0.236$, *SE* = .052, $p < 0.001$. When there were distracters present, the duration of total fixations to targets was longer than when there were no distracters, $\beta = 0.084$, *SE* = .020, $p < 0.001$. However, the effect of distracters was somewhat attenuated as participants read through the paragraphs, as indicted by the significant negative estimate for the serial order by distracter interaction, $\beta = -0.010$, *SE* = .003, $p = .0017$. And the duration of total fixations to targets decreased somewhat with the serial order of the sentences, $\tau = -0.010$, *SE* = .002, $p < .001$, as participants read through the paragraphs sentence by sentence.

The measures of working memory, processing speed, vocabulary, and inhibition were then added as additional person-level predictors of fixation duration along with their interactions with age group. The duration of first fixations to targets was shorter for readers who were faster on the processing speed measure, $\beta = -.001$, *SE* < .001, $p = .004$, and for readers who had better vocabularies, $\beta = .007$, *SE* = .002, $p < .001$, and for readers with better inhibition, $\beta = -.214$, *SE* = .051, $p < .001$. In addition, the duration of total fixations was shorter for readers with better inhibition, $\beta = -.944$, *SE* = .170, $p < .000$, and their advantage increased by the end of the paragraph, as indicated by the significant positive estimate for the inhibition by serial order interaction, $\beta = .019$, *SE* = .007, $p < .004$.

Duration of Fixations to Distracters

In general, there were few significant effects in the analysis of the duration of first fixations to the distracters but greater cumulative effects in the analysis of the duration of total fixations. First fixations to distracters were longer for older adults than for young adults, $\beta = 0.032$, *SE* = .014, $p < .001$; first distracter fixations increased with slower reading time, $\beta = 0.047$, *SE* = .022, $p < 0.001$. The duration of total fixations to distracters was also longer for older adults than for young adults, $\beta = 0.147$, *SE* = .042, $p < .001$; total distracter fixation duration also increased with sentence reading time, $\beta = 0.113$, *SE* = .042, $p < 0.001$. Additionally, the duration of total fixations to distracters decreased with the serial order of the sentences, as indicated by the negative estimate, $\tau = -0.009$, *SE* = .003, $p = .009$. However, this decrease in the duration of total fixations to distracters was attenuated for older adults, as indicated by the significant negative estimate for the age by serial order interaction, $\beta = -0.015$, *SE* = .004, $p < .001$. This decrease was also attenuated by sentence reading time, $-\beta = 0.009$, *SE* = .001, $p < 0.001$.

The individual differences measures were then added to the models as additional person-level predictors of fixation duration along with their interactions with age group or with reading time. The duration of first fixations to distracters was shorter for readers who were faster on the processing speed measure, $\beta = -.001$, *SE* < .001, $p = .003$, and for readers who had better inhibition, $\beta = -.220$, *SE* = .05, $p < .001$. Readers with better working memory had an slight advantage as indicated by the significant interaction for working memory by serial order for total fixation duration to distracters, $\beta = -.002$, *SE* < .0001, $p < .001$; readers who were faster on the processing speed measures also had a slight advantage as they read through the paragraph, as indicated by the significant processing speed by serial order interaction for the duration of total fixations, $\beta = -.0002$, $SE < .0001$, $p < .0001$; readers who had better vocabularies also had a slight advantage, as indicated by the significant vocabulary by serial order interaction, $\beta = -.0005$, $SE < .0001$, $p < .001$. However, readers with better inhibition had a larger overall advantage resulting in shorter total fixations to distracters, as indicated by the large negative estimate for inhibition, $\beta = -1.151$, $SE = .157$, $p < .000$. Further, this advantage increased by the end of the paragraphs as indicated by the significant positive inhibition by serial order interaction, $\beta = .042$, $SE = .007$, $p < .0001$.

Comprehension and Recognition

After reading the paragraphs, young and older adults were equally good at answering both factual comprehension questions, averaging 95% correct, $F(1, 65) = .25$, $p = .62$, and inferential questions, averaging 92% correct, $F(1, 65) = .09$, $p = .77$.

Older and young adults were equally good at recognizing target words (M_Y = 68% recognized, SD = 14; M_O = 74%, SD = 17), $F(1, 65) = 2.77$, $p = .10$, and distracters (M_Y = 49% recognized, SD = 22; M_O = 52%, SD = 26), $F(1, 65) = .37$, $p = .55$. Young adults were better at correctly rejecting foils (M_Y = 84% rejected, SD = 9; M_O = 78%, SD = 17) than older adults, $F(1, 65) = 5.57$, $p = .02$.

Discussion

In this study, older adults read more slowly than young adults and they fixed individual targets and distracters longer. Distracters also slowed reading times, especially for older adults. Most critically, whereas young adults appeared to learn to ignore distracters as they read through the paragraphs sentence by sentence, the older adults were less successful at learning to ignore the distracters and their reading time improved less across sentences in the paragraph. This interpretation, that older adults were less successful than young adults at learning to ignore the distracters, receives additional support from the analysis of fixations to the distracters themselves. Not only were older adults' fixations longer, but the decrease in fixation duration to distracters from sentence to sentence was attenuated for older adults. Hence, older adults spent .60 s on each distracter at the beginning of the paragraph and .53 s on each distracter at the end (a reduction of 12%), whereas young adults' fixations to the distracters declined from .20 s to .13 s by the end of the paragraph (a reduction of 35%). De Fockert et al. (2009) reported a similar finding: older adults were less able to suppress processing of irrelevant information, even when that information was consistently irrelevant for the duration of the experiment.

Learning to ignore distracters does appear to involve inhibitory control as readers with good inhibition relative to others in their age group, as measured by performance on the Stroop task, showed a reduced effect of distracters on overall reading time. In addition, their first and total fixations to distracters were shorter, especially by the end of the paragraphs. Having a better working memory, a larger vocabulary, and faster processing speed relative to others in your age group also contributed to learning to ignore distracters but the effects of these individual differences were much weaker than the effects of inhibition. Good inhibition appears to be critical in order to learn to ignore distracters. Learning to ignore distracters not only requires that the reader process context (e.g., Rush et al, 2006) and build up a semantic and conceptual representation of the topic as well as an inventory of relevant and irrelevant words progressively over the course of the paragraph but it also requires that the reader inhibit processing of irrelevant words that are not consistent with this representation and inhibit attempts to integrate them into the sentence and the paragraph.

The present findings also suggest an explanation for the different pattern of results reported by Kemper and McDowd (2006) and Connelly et al. (1991). The former, using a single-sentence task, reported no age differences in distracter processing. The latter, using a paragraph format, reported significant age differences in distracter processing. Young adults' performance may improve from one sentence to the next across a paragraph as they learne to ignore distracters whereas older adults' performance does not, revealing an age difference not present when performance is evaluated based on only a single sentence.

The present findings are also relevant to arguments about the processes underlying age-related inhibitory deficits. Hasher & colleagues (Hasher, Zacks, & May, 1999; see also Feyereisen & Charlot, 2008; Titz, Behrendt, Menge, & Hasselhorn, 2008) have outlined three inhibitory processes – access, deletion, and restraint. The present data appear to implicate the deletion function. That is, both young and old adults access distracting text, as indicated by the equivalent recognition memory performance in the two age groups. However, young adults quickly delete distracting text from the focus of attention, as indexed by their reading times and fixation patterns. Still, before any strong conclusions can be made about the locus of age related inhibitory deficits, additional work directly addressing these questions must be undertaken.

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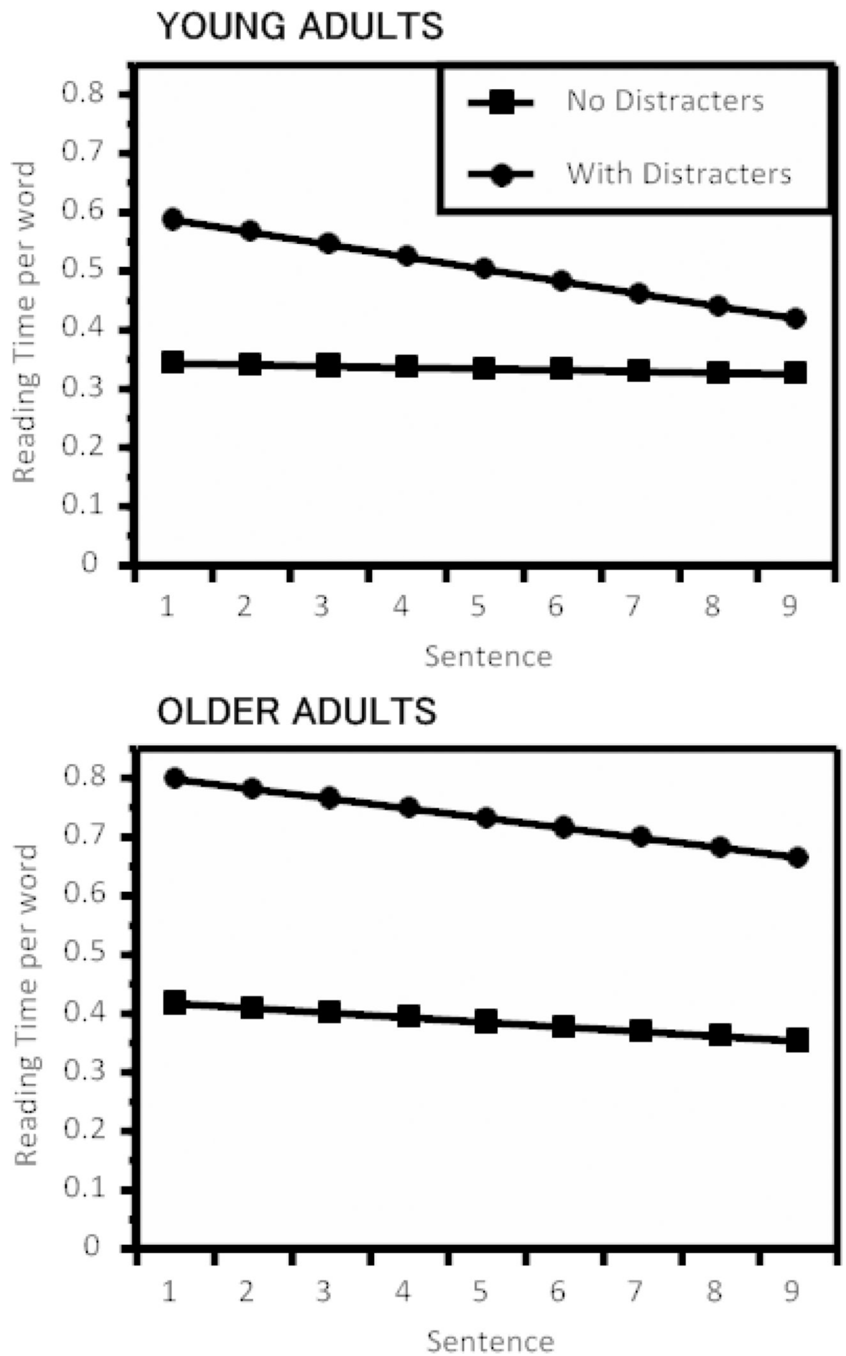

Figure 1.
Reading Time (seconds per word) as a Function of the Serial Order of the Sentences for Paragraphs with and without Distracters for Young versus Older Adults.

Table 1

Sample Paragraph with and without Distracters. Text and Targets were presented in Italic font; distracters were presented in Roman font. Targets and Distracters chosen for Analysis are indicated by Boxes.

Order	Without Distracters	With Distracters
1	*This is the first trip to Europe for Charlie.*	*This is the* sweep *first trip to* flute *Europe for* peanut *Charlie.*
2	*His school got a discount on his plane fare and hotel.*	*His school got a* goat *discount on his* news *plane* atom *fare and hotel.*
3	*As he boards he is thinking about how great it is going to be to see all of those places he has only read about.*	*As he* casino *boards he is* soil *thinking* father *about how great* center *it is going to be to* actor *see all of those* nurse *places he has only* goat *read* atom *about.*
4	*He is very excited about seeing Paris.*	*He is very* father *excited* soil *about seeing Paris.*
5	*Charlie has his English-French dictionary to*	*Charlie has his* sweep *English-French dictionary to*