Ageing and the Misperception of Words: Evidence from Eye Movements during Reading

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Abstract

Research with lexical neighbours (words that differ by a single letter while the number and order of letters is preserved) indicates that readers frequently misperceive a word as its higher frequency neighbour (HFN) even during normal reading (Slattery, 2009). But how this lexical influence on word identification changes across the adult lifespan is largely unknown, although slower lexical processing and reduced visual abilities in later adulthood may lead to an increased incidence of word misperception errors. In particular, older adults may be more likely than younger adults to misidentify a word as its HFN, especially when the HFN is congruent with prior sentence context, although this has not been investigated. Accordingly, to address this issue, young and older adults read sentences containing target words with and without an HFN, where the HFN was either congruent with prior sentence context or not. Consistent with previous findings for young adults, eye movements were disrupted more for words with than without an HFN, especially when the HFN was congruent with prior context. Crucially, however, there was no indication of an adult age difference in this word misperception effect. We discuss these findings in relation to the nature of misperception effects in older age.

Key Words: Eye Movements, Reading, Lexical Neighbours, Ageing

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Studies of eye movements during reading have proven invaluable for understanding how adult reading capabilities change in older age, even for healthy individuals who have no apparent visual or cognitive impairments. Amongst his many contributions to eye movement research, Keith Rayner and his colleagues published a series of articles that have majorly advanced our understanding of how eye movements during reading change with age (Rayner, Castelhano, & Yang, 2009, 2010; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Rayner, Yang, Castelhano, & Liversedge, 2011; Rayner, Yang, Schuett, & Slattery, 2013; Rayner, Jinmian, Schuett, & Slattery, 2014). Although not the first to investigate the effects of ageing on eye movements during reading (see, e.g., Kliegl, Grabner, Rolfs, & Engbert, 2004), Rayner and colleagues were the first to claim that older readers adapt to age-related reading difficulty by changing their reading strategy (Rayner et al., 2006). They also showed how the associated changes in eye movement behaviour might be modelled computationally (see also Laubrock, Kliegl, & Engbert, 2006).

In common with other ageing studies, Rayner et al. (2006) found that older adults (in this study aged 70-92 years) read more slowly and made more and longer fixations on words than younger counterparts (aged 18-34 years). The older adults also produced larger word frequency effects, by making disproportionately longer fixations on words that had a lower frequency of written usage and so were less familiar. Such findings were consistent with the older adults experiencing greater reading difficulty. But, in addition to these findings, Rayner et al. (2006) reported other qualitative differences in the eye movement behaviour of the two age-groups that appeared to reflect fundamental differences in reading strategy. In particular, compared to the young adults, the older adults made longer forward eye movements and skipped words more frequently (i.e., moved their eyes past words without fixating them), and were more likely to regress back to words. Rayner et al. suggested that these differences were attributable to older adults compensating for their slower processing of words by employing a more “risky” reading strategy, according to which they are more likely than young adults to infer the identities of words based on prior context and only partial word information. As a result, older readers are more strongly predisposed to anticipate upcoming word identities and so skip words more frequently, thereby speeding the progress of their eyes through text. But, as they are also more likely to misidentify words, older readers make more backward eye movements to reprocess words. Rayner et al. showed that these effects of ageing on eye movement behaviour could be simulated by the E-Z Reader model of eye movement control (e.g., Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Rayner, & Pollatsek, 2003). This required adjustment to the model's parameters to mimic lower acuity of older readers, slow the rate of lexical processing, increase effects of word frequency, and increase the probability of guessing (and sometimes misidentifying) the next upcoming word based on prior context.

Subsequent research has replicated, extended, and sometimes challenged some of the basic findings from this research (e.g., Jordan, McGowan, & Paterson, 2014; McGowan, White, Jordan, & Paterson, 2014; McGowan, White, & Paterson, 2015; Paterson, McGowan, & Jordan, 2013a,b,c; Payne & Stine-Morrow, 2012; Rayner et al., 2009, 2010, 2011, 2013, 2014; Risse & Kliegl, 2011; Wang, Li, Li, Xie, Chang, Paterson, White, & McGowan, 2016; Whitford & Titone, 2016). However, the notion that older adults are more likely to misperceive words has not been examined in detail, and so the present research investigated this issue more closely. Indeed, it was of particular concern for the present research that several eye movement studies with young adult participants show that individuals with good reading abilities often misperceive words during normal reading (Gregg & Inhoff, 2016; Perea & Pollatsek, 1998; Pollatsek, Perea, & Binder, 1999; Slattery, 2009). These errors were revealed by examining eye movements for words that have lexical neighbours. Lexical neighbours are words that differ by a single letter but have the same number and order of letters (Coltheart, Davelaar, Jonasson, & Besner, 1977). For instance, 'spice' is a neighbour of the word 'space'. Such words had already been used extensively in single word priming experiments to investigate mechanisms underlying the recognition of individual words, the results of which show that brief exposure to a word's neighbour as a prime can slow the subsequent recognition of that word (for a review, see Andrews, 1997). The eye movement studies added to these findings by showing that normal reading is disrupted when a sentence contains a word which has a lexical neighbour that has a higher frequency of written usage (Gregg & Inhoff, 2016; Pollatsek et al., 1999; Slattery, 2009). The implication of this finding is that, although the word's neighbour is never encountered in the text, its availability in the reader's mind has the capacity to disrupt reading. Indeed, according to this view, exposure to a word activates not only the lexical entry for that word but also lexical entries for its neighbours, and these compete for selection. Words that have a higher frequency of written usage are more familiar and so have a natural advantage in this competition. Consequently, the higher frequency neighbour (HFN) will sometimes win the lexical competition, with the result that the reader occasionally misperceives a word as its neighbour (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Davis, 2003; Grainger & Jacobs, 1994, 1996), and this is likely to disrupt reading. Slattery (2009) additionally showed that disruption to reading is even greater when the HFN is congruent with prior sentence context, indicating that word misperception is mediated by context.

However, research to date has not investigated if misperception effects change with age, although there is longstanding evidence for effects of ageing on lexical competition during spoken word recognition (e.g., Sommers & Danielson, 1999), and similar evidence from studies of isolated visual word recognition (McArthur, Sears, Scialfa, & Sulsky, 2015). Clear evidence for the greater use of context by older readers is also lacking (Madden, 1988; Stine-Morrow, Miller, Gagne, & Hertzog, 2008; Federmieir & Kutas, 2005; Federmieir, Kutas, & Schul, 2010); and even Rayner et al. (2006) failed to observed larger context effects for their older than younger adults, although the greater use of context to predict word identities is a key component of risky reading. It will therefore be important to investigate the influence of context on the misperception of words by young and older readers to gain a fuller understanding of how these effects might change with age. Accordingly, the present research examined if older adults are more susceptible to misperception effects caused by the availability of a word's HFN and its congruency with prior context. In our experiment, young and older adults read sentences that included a target word with or without an HFN (using stimuli from Slattery, 2009). In addition, two types of context were used: neutral and biased. In neutral contexts, both the target word and its HFN were congruent with the prior sentence context but only the target word was congruent with the post-target text. By comparison, in biased contexts only the target word was congruent with the prior sentence context. The logic of this approach was that the nature of the stimuli allowed a target word's HFN to receive bottom-up activation from its orthographically similar neighbour (i.e., the target word), and top-down activation from the prior context in neutral sentences, whereas any top-down feedback would be inhibitory in biased sentences and so should reduce the likelihood that the word would be misidentified.

Slattery (2009; see also Pollatsek et al., 1999) found that word misperception effects emerged relatively late in the eye movement record, in longer second-pass and total reading times for target words and an increased incidence of regressions to these words. The implication of these findings is that lexical competition between the target word and its HFN has little effect on the initial processing of words and disruption only occurs once the misidentification is detected. Such effects may therefore emerge relatively late in the eye movement record in the present experiment too. If the pattern of these effects is similar to that reported previously, there should be an interaction between target word type and context for the young adults, so that eye movements are disrupted more for target words with than without an HFN and this disruption is greater in neutral than biased contexts.

Our experiment will, in addition, reveal any differences in the eye movement behaviour of the young and older readers. A first concern will be to determine if the older readers show typical effects of age-related reading difficulty and evidence of more risky reading. If so, compared to the young adults, they should read more slowly and make more and longer fixations on words, but also make generally longer forward saccades, skip words more frequently, and regress back to words more often. But, crucially, the experiment will reveal if the pattern of misperception effects differs for the young and older readers. In particular, if the older adults use a more risky strategy to recognise words, they may be more susceptible to word misperception effects and so be more disrupted than the younger readers when sentences contain a target word with than without an HFN. In addition, if the older readers make greater use of context to anticipate word identities, they may be more likely to misidentify a target word as its HFN, and so experience greater disruption to reading than the young adult readers, in neutral compared to biased contexts.

Method

Participants. Twenty-eight young adults (M=20 years, range=18-29 years) and 28 older adults (M=69 years, range=65-77 years) were recruited from the University of Leicester and the surrounding community. All were native English speakers and reported that they did not suffer from visual or reading impairments. Participants were assessed for acuity at the viewing distance in the experiment using an ETDRS chart (Ferris & Bailey, 1996), and for contrast sensitivity using a Pelli-Robson chart (Pelli, Robson, & Wilkins, 1988). Acuity was greater than 20/35 (in Snellen values) for all participants and so within normal range. But, compared to the young adults, the older adults had lower acuity (young adults, M=20/18 range=20/14-20/25; older adults, M=20/25, range=20/17-20/35; $t(54)=5.63$, $p<.05$) and lower contrast sensitivity (young adults M=2.01, range=1.90-2.15; older adults, M=1.95, range=1.90-2.00; $t(54)=4.97$, $p<.05$), as is typical for these age-groups. The two groups were closely matched for years of education (young adults, M=14.8 years, range=13-19 years, older adults, M =15.8 years, range =11-22; $t(54)=1.64 = p >.05$) and all participants reported reading for at least several hours each week. Cognitive abilities were assessed using the Montreal Cognitive Assessment (MoCA) test, applying an exclusion criterion of <26/30. In addition, working memory (forward and backward digit span) and vocabulary were assessed using the Wechsler Adult Intelligence Scale (WAIS-IV). Young and older adults produced similar mean digit span scores (young adults, M=21/32, range=14-26; older adults, M=22/32, range=17-32; $t(54)=1.83$, $p>.05$). The older adults produced higher mean vocabulary scores than the young adults, however (young adults, *M*=44/57, range=29-55; older adults, *M*=53/57, range=43-57; $t(54)=6.50$, $p<.001$), consistent with previous indications of a vocabulary advantage for older adults (e.g., Ben-David, Erel, Goy, & Scheider, 2015; Keuleers, Stevens, Mandera, & Brysbaert, 2015).

Stimuli and Design. The target word stimuli were 44 word pairs comprising 44 words with a HFN and 44 control words that do not have an HFN (from Slattery, 2009). Target words were between 4 and 6 letters long and experimental and control words were matched for letter and syllable length (see Table 1). The experimental and control words were matched for lexical frequency using the CELEX (Baayen, Piepenbrock, & Gulikers, 1995) and SUBTLEX-UK databases (van Heuven, Manderab, Keuleers, & Brysbaert, 2015; see Table 1). The experimental words were intentionally selected so that their HFN had a higher lexical frequency, and the experimental and control words each had an average of two lower frequency neighbours (calculated using N-Watch; Davis, 2005). Each pair of target words could appear in the same location within two sentences frames, a neutral sentence frame and a biased sentence frame, producing a total of 88 sets of target words and sentence frames in these combinations. The target words were never the first or last words a sentence. For neutral sentence frames, the experimental and control words, and the experimental word's HFN, fitted plausibly with the prior sentence context, but only the target words, and not the HFN, were compatible with the post-target text. For biased sentence frames, only the target words, and not the HFN, were compatible with either the prior sentence context or post-target text (see Figure 1 for an example stimulus).

A 5-point plausibility rating scale administered to 12 participants (who did not take part in the eye movement experiment) showed that HFNs were a little more plausible than the target words in neutral contexts (HFN $M= 4.86$, target $M= 4.49$; $t= 2.96$, $p< .05$), and that target words were much more plausible than HFNs in biased contexts (target $M= 4.90$, HFN $M= 1.51$; $t= 23.49$, $p<.001$). This replicated the pattern of plausibility ratings reported by Slattery (2009).

A Latin Square was used to counterbalance sentence presentations for each age-group so that each participant saw a sentence containing each target word only once, but an equal number of sentences in each experiment condition, and target words were seen equally often in neutral and biased contexts across each age-group. The experiment therefore employed a mixed design with the between-participants factor age-group (young adult, older adult) and within-participants factors target word type (experimental, control) and context (neutral, biased).

Apparatus and Procedure. A tower-mounted EyeLink 1000 eye tracker (SR Research) recorded the gaze location of each participant's right eye every millisecond, although viewing was binocular. Sentences were displayed in Courier New font on a 20-inch monitor as high-contrast black text on a white background. At an 80cm viewing distance, each character subtended approximately 0.3° of visual angle, and so text was of normal size for reading (e.g., Rayner & Pollatsek, 1989).

Participants completed the visual and cognitive tests at the start of the experiment and were instructed to read normally and for comprehension. The eye-tracker was then calibrated using a horizontal three-point procedure. Chin and forehead rests were used to minimize head movements. Calibration accuracy was checked prior to the start of each trial to ensure accuracy >.3°and the eye-tracker was recalibrated as necessary. At the start of each trial, a fixation cross was presented to the left side of the display. Once the participant fixated this location, the cross disappeared and was replaced with a sentence, with the first letter of the sentence appearing at the same location as the cross. Participants used a response pad to indicate when they had finished reading each sentence. The sentence then disappeared and on 30% of trials was replaced with a comprehension question requiring a yes/no response. Participants responded to this question using the response pad.

Results

Accuracy in answering the comprehension questions that followed sentence presentations was generally high (M=92%), above 80% for all participants, and did not differ across age-groups (t<1), indicating that young and older adults comprehended the sentences equally well.

Following standard procedures, fixations under 80ms and over 1200ms were removed (2.2% of fixations). The remaining data were subjected to sentence-level analyses of reading times and eye movement behaviour and word-level analyses of eye movements for the target words. Sentence-level analyses examined sentence reading times and several standard measures of eye movements: average fixation duration, number of fixations, number of regressions (backward eye movements), and forward saccade amplitude (the average distance, in characters, traversed by forward eye movements). Word-level analyses examined a range of standard measures that were informative about processing that occurred during the initial analysis of target words and prior to a fixation to the right of these words (i.e., first-pass processing): word-skipping (the probability of not fixating a word during first-pass reading), first-fixation duration (the duration of the first fixation during first-pass processing of a word), single-fixation duration (the duration of the fixation on words receiving only one first-pass fixation), gaze duration (the sum of all first-pass fixations on a word), first-pass re-fixation probability (the likelihood of a word receiving more than one fixation during first-pass reading). We also examined measures sensitive to the later processing of the target words: re-reading time (the sum of all fixations on a word following a fixation to its right), regressions-in (the probability of a regression back to the target word), and total reading time (the sum of all fixations on a word).

The data were analysed using linear mixed effects models (LMEM; Baayen, Davidson, & Bates, 2008). This approach has the advantage over more traditional Analyses of Variance of simultaneously taking account of the separate sources of error variance associated with participants and stimuli in the same statistical model (e.g., Baayen, 2008). LMEMs were conducted using R (R Core Team, 2015) and the lme4 package (Bates, Maechler & Bolker, 2011). Measures of reading time, the number and duration of fixations, and the number and length of saccades (including the number of regressions in sentence-level analyses) were continuous, while the word-skipping and regression probability measures were dichotomous. Following standard procedures, a maximal random effects structure was used for continuous measures, and generalised linear models were conducted for dichotomous variables. Data for continuous measures above or below 2.5 standard deviations of each participant's mean for a given condition were removed. Log-transformation did not affect the pattern of results for analyses of continuous measures and so results derived from untransformed data are reported. For all analyses, t/*z* values >1.96 were considered significant. Additional analyses conducted with working memory and vocabulary scored included as co-variates produced no significant effects and so analyses are reported without these variables included. For sentence-level models, participants and stimuli (sentences in sentence-level analyses and target words in word-level analyses) were specified as crossed-random effects, and age-group was specified as a fixed factor in sentence-level models. For target word-level models, age-group, target word type and context were specified as fixed factors.

Sentence-Level Analyses. Sentence-level means are shown in Table 2. The young and older adults did not differ in sentence reading times, average fixation duration, number of fixations, length of forward saccades or number of regressions (all $t/z<1$). There was therefore no indication in these sentence-level measures of age-related reading difficulty.

Target Word Analyses. Means for the target-word level analyses are shown in Table 3. There was no significant main effect of age-group for first-fixation duration, single-fixation duration, gaze duration, re-reading time or total reading time (all t/z=<1.96). But, compared to the young adults, the older adults skipped the target words more often (young adults, M=16.3%, older adults, M=23.5%, β=.48, SE=.20, z=2.45), made fewer first-pass re-fixations on words (young adults, M=15.9%, older adults, M=8.6%, β=.77, SE=.26, z=3.02), and more regressions back to words (young adults, M=23.2%, older adults, M=32.2%, β=.45, SE=.17, z=2.65). Therefore, in line with the sentence-level findings, the older adults showed little indication of age-related reading difficulty, but skipped words more often and made more regressions compared to the young adults and so showed evidence of more risky reading.

Main effects of target word type were obtained in total reading times (β=14.69, SE=6.20, t=2.37), regressions-in (β=.25 SE=.07, z=3.43), and re-reading times (β=20.10, SE=5.93, t=3.39). These effects were due to more regressions, more fixations, and longer reading times for words with than without an HFN. No main effects of target word type were observed in word-skipping, first-fixation duration, single-fixation duration, gaze duration, or first-pass re-fixation probabilities (all t/zs<1.96). The availability of a HFN therefore did not affect the first-pass processing of target words but influenced later processing by increasing the probability of a regression back to the target words and the subsequent re-reading of these words. This also resulted in an increase in the number of fixations and total reading times for the words. This pattern of effects is consistent with readers initially misperceiving a target word as its HFN and re-processing the word following this initial misanalysis. Crucially, this effect of target word type was observed both for young and older adults and did not interact with age-group (all t/zs<1.96), and so it appears that word misperception effects were similar for both age-groups.

An interaction between target word type and context was obtained in total reading times (β=34.50, SE=12.40, t=2.78), and re-reading times (β=24.20, SE=11.86, t=2.04), but no other measures (all t/zs<1.96). For both total reading times and re-reading times, this interaction was due to larger increases in reading times for words with than without an HFN in neutral compared to biased contexts. The target word's HFN always fitted plausibly with the prior sentence text in neutral but not biased contexts and was incongruent with the post-target text in both contexts. Target words were therefore more likely to be misperceived as an HFN when this analysis was congruent with prior context and disruption to processing occurred once this analysis proved to be incongruent with the post-target context. This mediation of the word misperception effect by the congruency of the HFN with context is consistent with previous findings (Slattery, 2009). Crucially, however, there was no three-way interaction between target word type, context and age-group (all ts<1.96), and so no indication that this influence of context differed for young and older adults. Rather, it appears that young and older adults made similar use of context to guide their initial processing of words. Indeed, the very clear finding from the present research is that both young and older adults often misperceive a word as its lexical neighbour and that context has a rapid influence on these lexical processing decisions during reading for both age-groups.

In addition to the LMEM analyses, Bayes Factors (Kass & Raftery, 1995) were computed for each measure to assess the strength of evidence for null and alternative hypotheses for key comparisons. These were computed using the BayesFactor package (see Rouder, Morey, Speckman & Province, 2012) in R (R Core Team, 2015). Marginal likelihood was obtained using Monte Carlo sampling, with iterations set at 100,000 and the scaling factor for g-priors set to 0.5 (see Abbott & Staub, 2015). Following the interpretation categories set out by Vandekerckhove, Matzke and Wagenmakers (2014; adapted from Jeffreys, 1961), we interpreted Bayes Factors (BF) larger than 3 as providing weak to moderate support for a hypothesis, BF larger than 10 as providing strong support, while BF less than 1 were taken to provide evidence in favour of the null hypothesis.

For first-fixation and gaze durations, the analyses favoured models containing only a main effect of age-group (BF=195 and 7.51, respectively), indicating age differences in the first-pass processing of the target words. Analyses for single-fixation durations provided little or no support for any experimental model over the null model, however (all BF=<2.00). Models with a main effect of age–group only were also preferred for re-fixation probability and word-skipping (BF=6.87×10^{8} and 9.63×10^{6}, respectively), consistent with older adults skipping words more frequently, but also making fewer re-fixations on words, compared to young adults. For the likelihood of a regression to a target word, the analysis preferred a model containing main effects age, word-type and context, but no interactions (9.33×10^{15}). But, crucially, BFs for total reading times were highest for a model containing main effects of word type, context and a context x word type interaction (BF=6095.81), and for re-reading time for a model containing main effects of age-group, word type and context and a word type x context interaction (BF=1.52×10^{13}). BFs for models that included a 3-way interaction between age-group, word type and context received no support for total reading time (BFs<1). Moreover, while a model that included a three-way interaction between age-group, word type and context received weak support compared to a null effects model for re-reading time (BF=4.81), this model received no support when compared to the most-preferred model that did not include the three-way interaction (BF=<.001). The indication, therefore, is that a simpler model, which includes a word type x context interaction, but no three-way interaction including age-group, is substantially more likely, consistent with the view that there are no differences in the word misperception effects across adult age-groups.

Discussion

The present findings showed very clearly that word misperception effects commonly occur during normal sentence reading, so that readers often misread a word as its HFN, especially when the HFN is congruent with the prior sentence context. The findings also showed that misreading a word as its HFN has a relatively late impact on eye movement behaviour and, in the present experiment, this was observed in re-reading and total reading times for the target words and the incidence of regressions back to these words, but not measures sensitive to the early processing of these words. The indication, therefore, is that disruption to eye movements follows the detection of a misanalysis, typically when the misread word is incongruent with subsequent text, and may reflect efforts to repair this misanalysis by re-processing the misread word.

These findings are in line with findings from previous investigations of word misperception (Slattery, 2009), demonstrating their robustness. The present research aimed to extend these findings, however, by establishing if the effects of word misperception are greater for older readers, as a result of slower lexical processing and reduced visual abilities in later adulthood. Indeed, we argued that older readers may be more susceptible to such effects if they employ a more risky reading strategy to compensate for their poorer processing of words, as Rayner et al. (2006) proposed. In particular, we considered that if older readers are more likely than young adult readers to infer the identities of upcoming words based on only partial word information and prior context, as the account claims, they may be especially likely to misidentify a word as its HFN, and so produce greater disruption to reading. However, we were surprised to find no such effects. Instead, we found that the older readers were disrupted to a similar extent by the availability of a word's HFN, and showed very similar influences of context as the younger readers. Moreover, this finding was confirmed by further analyses that used Bayes Factors to assess the strength of evidence in support of null and alternative hypotheses, and showed that models for total reading times and re-reading times for the target words which included an interaction between word type (i.e., words with or without an HFN) and context, but no three-way intersection that included age-group, were most strongly favoured.

Such findings appear contrary to the view that older readers take a more risky approach to lexical identification, according to which they are more likely to "guess" the identities of words based on only partial word information and more reliant on context to guide these decisions. However, it was also of interest that we failed to obtain as clear evidence for age-related reading difficulty in the present experiment as reported in previous studies (e.g., Kliegl et al., 2004; McGowan et al., 2014; 2015; Paterson et al., 2013; Rayner et al., 2006). In particular, unlike in many other studies, there were no reliable age differences in reading times, number or average length of fixations, distance traversed by forward saccades or number of regressions for sentences, or fixations times for the target words in each sentence. We did, however, find that the older readers skipped the target words more frequently, made fewer re-fixations on these words, and were more likely to regress back to the target words compared to the young adult readers, and these findings were also confirmed by Bayes Factor analyses. The skipping and regression effects were of particular importance as they suggest that, despite the lack of evidence for age-related reading difficulty, the older readers' eye movement behaviour was characteristic of more risky reading. One possibility is that the older participants in our experiment were drawn from a population of more able older readers who were able to use this more risky reading strategy to read as effectively as the young adults and to avoid misperceiving words as frequently as less capable older readers. Indeed, it was noteworthy that the older adults in our study outperformed the young adults on a standardised test of vocabulary knowledge and this superior vocabulary may be protective against the effects of ageing on reading performance. It will therefore be important for future research to establish if less capable older readers show greater susceptibility to word misperception effects and to establish which factors are predictive of such errors.

It will also be important for future research to disentangle sensory and cognitive influences on the misperception of words by older readers. The stimuli used in the present experiment were words with and without a higher frequency orthographic neighbour. Consequently, a word and its HFN differed by the substitution of a single letter but this substitution did not necessarily preserve word shape and a target word and its HFN could be visually dissimilar (e.g., “story” & “stork”). Indeed, fewer than half of the HFNs in the current investigation preserved the shape of the target word. According to the risky reading account, older adult readers should misidentify upcoming words (during parafoveal processing) more frequently than younger adult readers. However, these misperception effects may not be driven by lexical competition from a word’s orthographic neighbours. Indeed, research suggests that a word’s orthographic neighbours are not strongly activated during parafoveal processing (Williams, Perea, Pollatsek, & Rayner, 2006). Consequently, it may be fruitful to investigate other forms of word misperception, including errors in which a word is misidentified for a visually similar word, which may also be an neighbour (e.g., misidentifying “brunch” as “branch”). Such words may be especially confusable for older readers due to visual declines in older age (for a review, see Owsley, 2011). Indeed, because older adults have lower acuity and reduced sensitive to visual detail, especially outside of central vision (e.g., Crassini, Brown, & Bowman, 1988), they may have particular difficulty discriminating between visually similar words in parafoveal vision. As a result, older adults may rely more heavily than young adults on coarse-scale cues to the length and shape of words (e.g., Jordan, McGowan, & Paterson, 2014; Paterson, McGowan, & Jordan, 2013b, 2013c; see also Allen, Smith, Lien, Kaut, & Canfield, 2009). Consequently, if older readers employ a more risky strategy in which they are more likely to infer the identities of words based on parafoveal visual input, they may be especially likely to make errors of this nature, especially when the misperception is congruent with context. Indeed, it may be valuable to determine if age differences are observed in other examples of the shallow-processing of text in which words are frequently misperceived in order to maintain local or global coherence (e.g., Christianson, 2016: Sanford & Sturt, 2002).

In sum, we examined if the more risky reading behaviour attributed to older adults leads older readers to more frequently misidentify words as their higher frequency lexical neighbours, especially when the neighbour words are congruent with prior sentence context. However, while the unusually highly-performing older adults in our study showed evidence of risky reading, they produced a very similar pattern of word misperception effects as the skilled young adult readers. The indication, therefore, is that high-performing older readers show standard effects of lexical competition and contextual predictability, although it remains to be determined if these effects differ for less able readers, and also if older adults are especially prone to misidentifying words that have visually as well as orthographically similar counterparts.

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Figure 1.

An Example Sentence in Each Condition.

Context	Stimulus type	
Neutral context	Experimental	Due to the freezing rain, the *brunch* (branch) was postponed a week.
	Control	Due to the freezing rain, the *buffet* was postponed a week.
Biased context	Experimental	Everyone said that the food at the *brunch* (branch) was simply magnificent.
	Control	Everyone said that the food at the *buffet* was simply magnificent.

Target words are shown in italics and the HFN in parentheses.

Table 1. Target Word Properties

Variable	Experimental	Control	Neighbour
Mean number of letters	5.1	5.0	5.1
Mean number of syllables	1.2	1.3	1.3
Lexical Frequency (CELEX-frequency per million)	13.02	14.10	130.00
Lexical Frequency (SUBTLEX-UK-Zipf-values)	3.75	3.82	4.97
Mean number of low frequency neighbours	2	2	4

Table 2: Means for Sentence-Level Measures

Measure	Age-Group	
	Young	Older
Sentence Reading Time (ms)	3196 (24)	3154 (26)
Average Fixation Duration (ms)	257 (0.8)	254 (0.8)
Number of Fixations	11.8 (.1)	12.3 (.1)
Progressive Saccade length (chars)	7.2 (.03)	7.2 (.03)
Number of Regressions	2.54 (.04)	2.64 (.04)

The Standard Error of the Mean is shown in parentheses

Table 3: Means for Target Word-Level Measures

Measure		Neutral Context		Biased Context	
		Experimental	Control	Experimental	Control
Word-Skipping (%)	Young	16.1 (2)	14.0 (1.4)	17.4 (1.6)	17.8 (1.6)
	Older	22.9 (1.7)	23.5 (1.7)	24.3 (1.8)	23.1 (1.7)
First-Fixation Duration (ms)	Young	234 (3)	235 (3)	236 (3)	237 (4)
	Older	245 (3)	244 (3)	241 (4)	254 (4)
Single-Fixation Duration (ms)	Young	238(4.7)	239(3.9)	245(4.7)	242(4.5)
	Older	251(4.2)	248(4.7)	247(4.3)	260(4.4)
First-Pass Refixation Probability (%)	Young	16.8 (1.6)	16.8 (1.6)	14.6 (1.6)	15.4 (1.7)
	Older	8.6 (1.3)	7.4 (1.2)	9.7 (1.4)	8.8 (1.3)
Gaze Duration (ms)	Young	269 (5)	270 (5)	266 (5)	268 (5)
	Older	258 (4)	258 (4)	260 (4)	271 (5)
Regression-in (%)	Young	30.1 (2.0)	22.8 (1.8)	20.6 (1.8)	17.9 (1.7)
	Older	38.9 (2.1)	35.3 (2.0)	29.1 (2.0)	24.2 (1.9)
Re-reading Time (ms)	Young	136 (8.7)	106 (8.6)	92 (8.2)	74 (7.2)
	Older	180 (11.2)	143 (9.2)	115 (8.6)	113 (9.2)
Total Reading Time (ms)	Young	394 (19.1)	368 (18.0)	348 (15.9)	338 (17.2)
	Older	400 (27.1)	363 (25.5)	345 (22.5)	350(24.3)

The Standard Error of the Mean is shown in parentheses