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Hyphens for disambiguating phrases: effectiveness for young and older adults

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Abstract The purpose of this study was to investigate whether hyphens that disambiguate phrasing in ambiguous sentences influence reading rate and reading comprehension for younger and older adults. Moreover, as working memory (WM) has been implicated in age-related changes in sentence comprehension for both auditory and written materials, we asked if it contributed to comprehension of our sentences with hyphenated and non-hyphenated ambiguous noun phrases (NPs), predicting that the hyphens would reduce WM load. Twenty younger ($M = 24$ years) and 20 older ($M = 73$ years) adults read sentences with either ambiguous or non-ambiguous NPs that were either hyphenated or not. Both reading times for the sentences and accuracy on Yes/No questions were measured. Results indicated that younger adults read sentences more rapidly than the older participants whether sentences were presented word-by-word or as complete sentences. Both younger and older adults read sentences with ambiguous hyphenated NPs faster than sentences with ambiguous non-hyphenated NPs. Yes/No question accuracy distinguished reading of the sentences with ambiguous hyphenated phrases from those with ambiguous non-hyphenated phrases for older, but not for younger adults. Regression analyses showed that age contributed to both accuracy and reading times on this task, whereas WM did not.

Keywords Phrase ambiguity · Hyphenation · Comprehension · Reading rate

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Introduction

Many factors contribute to the difficulties older adults may have with reading comprehension. Some of these difficulties are due to changes associated with aging itself, e.g., decreased vision, diminished speed of processing, reduced working memory (WM) capacity; others are due to characteristics of the materials, e.g., unfamiliar contents, poor legibility, increased syntactic complexity. The latter make reading harder for everyone but may interact with the cognitive changes associated with aging to render reading comprehension even more difficult for older adults (e.g., Salthouse, 1996; Park, 2000).

Research has demonstrated that adjusting and editing text can facilitate older adults' reading comprehension (e.g., Liu, Kemper, & Bovaird, 2009; Gausman, Benson, & Forman, 2002). One way to adjust reading material is to reduce sentence-level complexity, as Kemper, Jackson, Cheung, and Anagnopoulos (1993) demonstrated. Through regression analysis, Kemper et al. concluded that sentences that were low on propositional density and limited in the amount of embedding they contained were more accurately understood by older readers than those with greater propositional density and more embedding. Young adults read all types of sentences faster and understood all types of sentences more accurately than older adults, regardless of level of propositional density and amount of embedding. The authors thus recommend decreasing propositional density and embedding to facilitate reading for older adults.

We posited that another way to facilitate reading for the elderly would be to provide optimal punctuation that would facilitate parsing. We selected ambiguous noun phrases (NPs consisting of a noun with a two-word modifier, e.g., *tart cherry farmers*) and manipulated use of non-obligatory hyphenation that can disambiguate the phrases. This study investigated the effect of hyphens on ambiguity resolution at the phrase level in sentences. Any differences between the effects in younger and older adults, we reasoned, would lead to strategies for facilitating reading in older readers.

This study focused on sentence-level reading comprehension so we next review what is known about it as it relates to aging and the cognitive changes associated with aging.

Sentence comprehension

Sentence-level comprehension requires a combination of word-level processing skills and text-based processing skills. Text-based processing skills enable the reader to integrate meanings across words and to segment the information into 'idea units' or propositions (Stine, 1990). Such text-based processing skills presumably include both additional linguistic ones beyond lexical access (namely, morphological and syntactic processing) and cognitive ones that interact with them. No age-related changes have been reported for these linguistic skills per se, but a set of cognitive ones have been demonstrated to change with advancing age, implicating reading comprehension abilities. The three skills most closely linked to the current study are processing speed, inhibition of distracting material, and WM.

Salthouse (1996) developed an important framework to explain cognitive aging effects in light of processing speed. This framework suggests that nearly all age-related variance on almost any kind of cognitive task can be accounted for by knowledge of the rate at which a person makes speeded comparisons on perceptual tasks. With respect to processing speed at the sentence level, slower reading times of older adults appear to indicate that they spend more time integrating material which resulted in interpreting sentences differently (Kemper, McDowd, Metcalf, & Liu, 2008). Moreover, reading under time constraints appeared to diminish older adults' reading comprehension accuracy relative to younger adults (Norman, Kemper, & Kynette, 1992).

The role of inhibitory function is less clear-cut at the sentence level than that of processing speed is. A series of studies showed that older readers experience a breakdown of inhibition when confronted with texts containing distracter words printed in different typefaces (e.g., Carlson, Hasher, & Zacks, 1995; Zacks, Hasher, & Li, 2000). These studies suggest that younger adults are able to inhibit processing the distracting material whereas older adults' poorer performance on inhibition results in slowed reading times and impaired comprehension as the older adults attempt to integrate the distracters with the text. However, Kemper and McDowd (2006) demonstrated that younger adults also attempted to understand the distracters along with the target sentences. In this study, younger and older adults read sentences with single-word distracters in either italic or red font. Both the younger and older participants spent comparable time looking at the distracters.

Difficulties with inhibition were also not evident in a study by Newsome and Glucksberg (2002) where participants, after reading sentences containing metaphors, responded to metaphor-relevant and metaphor-irrelevant properties. Older and younger participants responded equally slowly after a literal prime and equally fast after a metaphor prime.

The third cognitive process that has been related to changes in comprehension at the sentence level in older readers is WM function (e.g., De Beni, Borella, & Carretti, 2007). The cognitive construct known as WM lets listeners and readers simultaneously process and store a limited amount of incoming information (e.g., Gathercole & Baddeley, 1993; Baddeley, 2003). Because of its limited capacity, high-demand processing, such as that required to parse complex linguistic structures, can overload the WM system. Thus, WM capacity differences, as measured, for example, by the Reading Span test (Daneman & Carpenter, 1980) have been linked to the ability to process syntactic ambiguity (e.g. Stine-Morrow, Ryan, & Leonard, 2000; Miyake, Just, & Carpenter, 1994). Conflicting results from seminal studies in the field are the cause of an ongoing debate. The debate centers around the fact that some researchers assign a large role to WM in language processing (e.g., Just & Carpenter, 1992; Miyake, Just, & Carpenter, 1994). They propose that both storage and processing components of WM draw from the same resource pool. Other researchers (e.g., Waters & Caplan, 2005; DeDe, Caplan, Kemtes, & Waters, 2004) argue for a separate WM resource devoted only to syntactic processing.

One area being investigated is the role of on-line versus off-line data. On-line tasks are tasks in which participants assign meaning at the time of reading (e.g. via tests of word-by-word reading) and off-line tasks are tasks in which the participants are required to understand the material and perform other tasks, such as sentence and picture matching. A second topic that is unresolved is the influence of individual WM capacity differences on language processing (Kemper, Crow, & Kemtes, 2004). Across the lifespan, readers and listeners can be assessed as low-span (LS) or high-span (HS) processers. With respect to age, older adults have demonstrated varying performance depending on the on-line/off-line nature of the experimental tasks and individual WM differences.

The on- and off-line contrast was investigated by Kemtes and Kemper (1997). They examined on-line reading times and off-line reading comprehension of syntactically ambiguous sentences by younger and older adults. Both main verb and relative clause ambiguities were investigated. Older readers demonstrated slower reading times than younger readers, however, within the older group, HS readers read faster than LS readers. Similarly with comprehension measures, HS older readers answered True/False questions more accurately than LS older readers. The authors concluded that off-line measures can serve to investigate age-related decline in language processing in relation to WM.

In contrast, Waters and Caplan (2005) argue that off-line performance by older or LS readers does not reflect syntactic processing, per se, but, more likely, what they term "sentence review processing." In their study, younger and older adults listened to semantically plausible and implausible sentences and performed an off-line plausibility judgment task. Performance by older and younger adults was comparable on two of the three sentence comparisons in both the simple and complex forms. The authors concluded that on-line syntactic processing is not affected by age and that separate WM resources, which remain stable across the lifespan, are available for syntactic processing .

Questioning separate WM resources for syntactic processing is a study by Kemper and Herman (2006) in which age and WM capacity were investigated. In this study, younger and older adults were asked to remember a variety of NPs while reading syntactically complex object-cleft sentences (e.g., *It was Kenneth that Robert thanked after winning the race*) and simpler subject-cleft sentences (e.g., *It was Kenneth that thanked Robert after winning the race*). In addition, comprehension questions followed reading of the sentences. The authors compared reading times across three regions in both types of sentences (Region 1 included the sentence initial cleft and was the same for both sentence types, Region 2 included a NP and verb and the word order varied between the two types of sentences, and Region 3 included the sentence final prepositional phrase and was the same for both sentences). Of the three regions only the second region distinguished subject-cleft sentences from object-cleft sentences. Whereas younger adults responded to both the overall imposed memory load and to a more specific interference caused by the form of NP to be remembered, older participants responded only to the more general form of memory load that resulted in slower on-line reading times. The authors point out that a WM theory specifying separate resources for syntactic processing (e.g., that of Waters and Caplan) cannot explain the different performance by younger and older adults on the tasks described above. They concluded that memory load and syntactic processing most likely draw on the same WM capacity. Thus, raising memory load, increasing syntactic complexity, or decreasing memory capacity (which is associated with aging) will increase processing time and decrease comprehension.

In summary, the literature on processing written sentences is not fully consistent concerning the roles of processing speed, inhibitory function, WM capacity and age. Individual differences (e.g., in WM) seem to be correlated to age-related decline in reading comprehension as well. One conclusion that one must draw is that for older adults, reading comprehension at the sentence level decreases when complex structures are processed. Furthermore, within the set of (syntactically) complex sentences, older adults' reading comprehension is further reduced when WM demands are high. To best facilitate reading comprehension in older adults, then, we must attempt to reduce WM load and/or syntactic complexity. Kemper et al. (1993) demonstrated that older adults' ($M = 78.2$ years) reduced reading rates and comprehension were most apparent with texts that contained propositionally dense sentences and complex syntactic structures. In this study, participants read a series of popular texts out loud and then answered a set of multiple-choice questions about them. A regression analysis of the older adults' reading rates and comprehension rates indicated that propositional density and amount of embedding (e.g., relative and comparative clauses) most negatively affect comprehension. When one of the paragraphs was revised to be of lower propositional density (e.g. by repeating terms) and to contain fewer embedded clauses, comprehension improved for older readers.

To assess whether reading comprehension of syntactically complex sentences can be enhanced by reducing WM load in additional ways for older adults, we investigated the disambiguating properties of hyphens in sentences containing ambiguous and non-ambiguous NPs. In this type of phrase, the ambiguity can be resolved by means of hyphens (e.g. different-word list vs. different word-list). Whereas in speech, such phrasal ambiguities are resolved by prosody; in written language, hyphens can take its place in facilitating the intended parsing.

Hyphenization

As indicated in the *Chicago Manual of Style*, *15th edition* (2003), the use of hyphens in English is not prescribed with "hard-and-fast" rules, but rather follows general patterns. For example, an 'open compound' is spelled as two or more words, as in *high school*. A 'hyphenated compound' is spelled with one or more hyphens, as in *mass-produced* or *learning-disabled*. A 'closed compound' is spelled as a single word, as in *birthrate*. With frequent use, over time, open and hyphenated compounds tend to become closed compounds (e.g., *on line*, *on-line* and *online*).

In addition to such general patterns, the style manual reports, there are several guiding rules. One such rule requires a hyphen when an adjective + noun combination precedes a noun, as in 1, but not when the adjective + noun combination follows the noun, as in 2:

1. A middle-class neighborhood.
2. The neighborhood is middle class.

The Publication Manual of the American Psychological Association, fifth edition (2002) adds that language is ever expanding and that *temporary compounds* develop. The publication manual explains that '*temporary*' means that the compound may occur on one occasion or in one context. A reason to use a hyphen in a *temporary compound,* according to this manual, is that the combination of words may be misinterpreted by the reader, as in the example of 'fast-food service' versus 'fast food-service.' A hyphen is added to show that 'food-service' and 'fast-food' are the intended compound nouns.

Sentence-level ambiguity-resolution has been a frequent topic in research on language comprehension (e.g., Frazier & Rayner, 1987; MacDonald, Just, & Carpenter, 1992; Kemper, Crow, & Kemtes, 2004), but the focus has been mainly on garden-path sentences in which the readers start parsing the sentence one way but then must switch to an alternative parsing at the point when the original one proves problematic (e.g., *The author wrote the novel was likely to be a best-seller*). Such sentences, we have observed, are less often the cause of ambiguity in day-to-day reading than sentences with the ambiguous NPs we study here to determine the particular effect of disambiguating hyphens.

To investigate the disambiguating properties of hyphens in sentences containing ambiguous and non-ambiguous noun phrases (NPs), we based our hypotheses on the research summarized above. We hypothesized that younger adults would read sentences containing ambiguous NPs faster and demonstrate more accurate comprehension than older adults generally. We further hypothesized that older readers, and perhaps younger ones as well, would demonstrate increased reading comprehension and faster reading speed for sentences with hyphenated ambiguous NPs than for those with non-hyphenated ambiguous NPs based on the rationale that the hyphens would constrain parsing of otherwise confusing *temporary compounds,* thus minimizing WM load. With respect to high-WM span and LS participants, we hypothesized that older and younger HS readers would outperform their LS peers on off-line reading comprehension.

Method

Participants

Forty subjects participated in the study: 20 younger adults (*M* age = 24, range = 19–34) and 20 older adults (*M* age = 73, range = 65–79). Both participant groups were recruited through fliers in a small university town 2 h outside NYC. All participants reported no significant medical history, in addition, the older participants reported that they were aging normally and living independently. Participants were all right-handed and native speakers of English. None of the participants reported vision problems for reading, and those who required glasses used them for this study. The two groups were similar in educational background; the younger participants had a mean of 15.5 years of education (SD = 1.1), and the older participants had a mean of 16.5 years of education (SD = 2.2), $t\ (38) = 2.04$, $p > .05$. The younger adults scored higher on the reading span test, (*M* young = 4.3, SD = 1.27) than the older adults (*M* older = 3.0, SD = .92), $t\ (38) = 2.63$, $p = 0.01$. The groups were balanced for gender; 12 females in the younger participant group versus 11 female participants in older participant group. All were paid for participation.

Materials

In order to provide natural stimuli that our participants might encounter in everyday reading, sentences for this study were collected from newspapers (*The New York Times*, *The Boston Globe*, *The New Paltz Times*), magazines (*The Economist*, *The Smithsonian*) and advertisement material and then modified as necessary to be context independent, e.g., pronouns were substituted for proper names. A group of three native-English speakers rated the sentences as ambiguous or not, and only items on which all three concurred were included in either the ambiguous or non-ambiguous categories.

The stimulus set consisted of four types of sentences; ambiguous and non-ambiguous, hyphenated and non-hyphenated (twelve of each type in the stimulus set):

Ambiguous, hyphenated (without the hyphen, both readings are possible)
He drove the little-used car from New York to Chicago.
Non-ambiguous, hyphenated (without the hyphen, only one reading is reasonable)
The nursing-home resident organized the activities.
Ambiguous, non-hyphenated (both readings are possible)
He drove the little used car from New York to Chicago.
Non-ambiguous, non-hyphenated ('home-resident' is not a likely phrase)
The nursing home resident organized the activities.

All four types of sentences were balanced for number of syllables ($M = 13.67$, $SD = 2.45$) with length in words ranging from 5 to 14 words. A Yes/No question was written for each sentence; it required the participant to verify the ambiguous or non-ambiguous nature of the sentence. Half of the Yes/No questions had "Yes" as answer, the other half had "No" as answer (e.g., the sentence '*He drove the little-used car from New York to Chicago*,' was followed by '*Is this about a small car*?'). Order of these questions was pseudo-randomized such that there were never more than two in a row that had a given answer.

Procedure

All participants were tested individually. After they completed the reading span task, they did the experimental self-paced reading task.

To assess WM capacity, the adaptation of the reading span task developed by Harrington and Sawyer (1992) was administered. In the reading span task, participants read aloud sets of an increasing number of sentences presented on a computer screen. The sentences were presented one at a time and participants paced themselves through each set by pressing the spacebar when they were ready for the next sentence. After presentation of the last sentence in each set, the participants were signaled verbally to write down all the final words from that set which they recalled. We chose to ask our participants to write their answers down to slow down the fast-paced nature of this task, which is especially reassuring for older participants. A more practical reason is that it provides a record of the participants' writing and responses. The task consists of three sets each of two, three, four, and five sentences, yielding a total possible score of 42 words recalled per task. For each participant the total number of correctly recalled words was calculated.

Within each participant group (younger and older readers), participants were ranked using the mean raw scores on the reading span task as this permitted us to divide the participants (younger and older readers) into high- and LS readers. The HS ($M = 5$, SD = .62) and LS ($M = 2.85$, SD = .48) groups were used to calculate the role of WM capacity in this study.

The experimental self-paced reading task was programmed using E-Prime (Schneider, Eschman, & Zuccolotto, 2002). Participants read 48 sentences twice (once presented word-by-word, once presented as whole sentences) from a computer screen. Participants were instructed to read the sentences to themselves, as fast as possible, but carefully enough to answer the Yes/No questions that followed each sentence. They were familiarized with the task through four training items. In addition to measuring comprehension, the Yes/No questions ensured that readers were paying attention to the sentences rather than just pressing the response key without reading the sentence. Even though both word-by-word and whole sentence presentations were followed by Yes/No questions, only the comprehension data from the whole-sentence presentation was analyzed here, as that reflects the natural reading process.

The sentences were presented in two conditions. Each condition was preceded by separate instructions. In one condition, the whole-sentence reading condition, complete sentences appeared in a single line centered on the computer screen. Participants were instructed to press the spacebar to indicate when they had completed reading the sentence. Then the sentence would disappear and a Yes/No question would appear. Participants were instructed to hit a key marked 'Y' to answer 'Yes' or a key marked 'N' to answer 'No' on the Yes/No questions. Hitting one of these keys would automatically activate presentation of the next stimulus sentence.

In the other condition, the word-by-word reading condition, sentences appeared one word at the time on the screen. Hyphenated phrases were presented as a single word. The participants were instructed to hit the spacebar to advance to the next word and to indicate that they had read the final word in the sentence. In the word-by-word condition, sentences did not end in a punctuation mark to prevent participants from slowing down and reading the last word in a sentence more slowly, which would bias the reading times. Only one word at a time would appear in the center of the screen. Instructions for the Yes/No questions were identical to the first condition.

Because pressing the spacebar determined the length of time that each sentence (in the whole-sentence condition) and each word (in the word-by-word condition) was displayed, the participant had full control over the rate at which the stimuli were presented. The computer measured the time between each key-press response, and this gave a measure of how long each stimulus (sentence or word) was displayed to each reader.

Half of the young adults and half of the older adults were first presented with the whole sentence condition, followed by the word-by-word sentence condition. The other half of the participants was presented with the conditions in the opposite order. Reversing the order of presentation controlled for faster reading times on the second reading of a given sentence. Such a design resulted in more variation in reading times within groups, so significant condition-related differences are all the more robust.

Results

Results of the comprehension findings (whole-sentence condition) are presented first, followed by the on-line reading times (word-by-word condition) findings. The primary analysis of all dependent measures was performed with a 2 (age group) $\times$ 2 (ambiguous with and without hyphenation) $\times$ 2 (HS and LS) ANOVA. Both an analysis with the subjects as random, $F1$, and an analysis with items as random, $F2$, are reported. In the final section differences in age and WM are examined by means of a regression analysis.

Reading comprehension

This study set out to clarify whether younger and older adults comprehend ambiguous phrases more accurately with or without disambiguating hyphens and whether younger adults, compared to older adults, demonstrate comparable benefits. Reading comprehension measures for younger and older participants groups are presented in Table 1.

The results of the analysis of variance were as follows. There was both a reliable main effect for age, $F1$ (1, 38) = 4.39, $p = .03$; $F2$ (2, 46) = 6.19, $p = .016$, and for hyphenation, $F1$ (1, 38) = 44.02, $p < .001$; $F2$ (2, 46) = 20.54, $p < .01$. The significant interaction of age and hyphenation in the participant analysis indicates improved comprehension for older adults when ambiguous phrases are disambiguated by hyphens, $F1$ (1, 38) = 5.47, $p = .02$; $F2$ (2, 46) = 1.17, $p = .18$. No further main effects or interactions were evident. A Student t test indicated that differences between the two participant groups were not significant for the

Table 1 Reading comprehension accuracy (out of 6)

	Younger participants	Older participants
Ambiguous sentences		
Ambiguous hyphenated (SD)	5.4 (.62)	5.5 (.51)
Ambiguous non-hyphenated (SD)	4.8 (.49)	4.1 (.73)
Non-ambiguous sentences		
Non-ambiguous hyphenated (SD)	4.3 (.97)	4.6 (.50)
Non-ambiguous non-hyphenated (SD)	5.3 (.67)	5.5 (.52)

hyphenated sentences, t (38) = −.56, p = .57, but were significant for the non-hyphenated sentences, t (38) = 3.12, p = .003.

An interesting, but reverse, trend was seen for the comprehension of non-ambiguous sentences. Young and older adults both demonstrated more accurate comprehension of non-ambiguous sentences without hyphens and less accurate comprehension of non-ambiguous sentences with hyphens. There was a reliable main effect for hyphenation, $F1$ (1, 38) = 7.74, p = .02; $F2$ (2, 46) = 18.54, p = .18 and a non-significant interaction of age and hyphenation, $F1$ (1, 38) = 3.25, p = .09; $F2$ (2, 46) = 11.34, p = .15. The interaction of age and hyphenation indicated that both participant groups were more accurate in answering Yes/No questions about non-hyphenated non-ambiguous sentences than hyphenated non-ambiguous sentences.

Differences between the two participant groups were neither significant for the non-hyphenated non-ambiguous sentences, t (38) = −1.62, p = .11, nor for the hyphenated non-ambiguous sentences, t (38) = −0.6, p = .55. As for HS readers and LS readers, the interaction between span and hyphenation was non-significant for both ambiguous sentences, $F1$ (1, 38) = 2.22, p = .12; $F2$ (2, 46) = 2.45, p = .09, as well as non-ambiguous sentences, $F1$ (1, 38) = 2.53, p = .19; $F2$ (2, 46) = 4.12, p = .19. HS readers and LS readers answered the Yes/No questions about hyphenated ambiguous sentences (*M* HS = 5.6, SD = .50, *M* LS = 5.3, SD = .57), and non-hyphenated ambiguous sentences (*M* HS = 5.5, SD = .51, *M* LS = 5.3, SD = .55) with comparable accuracy. Differences between the HS and LS groups approached significance for the hyphenated sentences, t (38) = −1.76, p = .09, but did not for the non-hyphenated sentences, t (38) = −1.62, p = .11.

Comparable to the results of the younger and older groups, the HS readers and LS readers answered the Yes/No questions about non-ambiguous sentences without hyphens more accurately (*M* HS = 5.6, SD = .6, *M* LS = 5.3, SD = .57) than the non-hyphenated ambiguous sentences (*M* HS = 4.4, SD = .88, *M* LS = 4.5, SD = .69). Differences between the HS and LS groups were neither significant for the non-hyphenated non-ambiguous sentences, t (38) = −1.02, p = .13, nor for the hyphenated sentences, t (38) = −0.8, p = .45.

On-line processing

In addition to accuracy and RT measures per sentence, and RT measures per word, in order to evaluate the effects of resolved and unresolved ambiguity on sentence processes after the crucial unit, word-by-word reading times were averaged within three specific regions of the sentence that were balanced for length in syllables across sentence types (ambiguous, non-ambiguous, hyphenated, and non-hyphenated sentences): Region 1 included the text before the compound phrase (approximately 11 syllables), Region 2 included the compound phrase which was either hyphenated or non-hyphenated (approximately 6 syllables), and Region 3 included all the text after the compound phrase (approximately 13 syllables).

Word-by-word reading times, i.e., on-line processing, were averaged within the three specific sentence regions. Reading time measures for younger and older

Table 2 Reading times for ambiguous sentences in milliseconds

	Younger participants	Older participants
Region 1		
Hyphenated sentences (SD)	197 (46)	240 (61)
Non-hyphenated sentences (SD)	186 (58)	274 (77)
Region 2		
Hyphenated sentences (SD)	243 (61)	333 (87)
Non-hyphenated sentences (SD)	304 (85)	473 (99)
Region 3		
Hyphenated sentences (SD)	330 (67)	425 (77)
Non-hyphenated sentences (SD)	403 (86)	530 (92)

participants groups are presented in Table 2. Times are reported in milliseconds per syllable.

Region 1: material before the ambiguous phrase

There was a significant main effect for age whereby younger adults read faster than older adults, $F1$ (1, 38) = 38.65, $p < .001$, $F2$ (2, 46) = 31.84, $p < .001$. No other significant effects or interactions were found for Region 1 (see Table 2).

Region 2: the compound phrase

Two main effects were present, namely an effect of age group, $F1$ (1, 38) = 40.96, $p < .001$, $F2$ (2, 46) = 6.38, $p = .015$ (younger adults were faster than the older adults), and an effect of hyphenation, $F1$ (1, 38) = 24.73, $p < .001$, $F2$ (2, 46) = 12.36, $p < .01$ (Region 2 materials were read faster for sentences with hyphenation than for those without hyphenation). A reliable interaction between age and span was present, indicating that within each age-group the HS readers were the fastest readers of Region 2. The second significant interaction was found between age and hyphenation, $F1$ (1, 38) = 3.86, $p = .05$, $F2$ (2, 46) = 7.43, $p = .012$. While both young and older adults read hyphenated compounds faster than non-hyphenated compounds, this difference was greater for the older adults than for the younger ones.

Region 3: all material after the compound phrase

Significant main effects for age, $F1$ (1, 38) = 50.64, $p < .001$; $F2$ (2, 46) = 25.32, $p < .01$, span, $F1$ (1, 38) = 4.04, $p = .048$; $F2$ (2, 46) = 7.07, $p = .03$, and hyphenation, $F1$ (1, 38) = 14.91, $p = .002$; $F2$ (2, 46) = 12.05, $p = .003$ were present. Region 3 was read faster by younger adults, by readers with a high reading span and when the sentences contained hyphens that disambiguated the compound. A significant interactive effect was present for age $\times$ span for Region 3; in both age groups the HS readers demonstrated the fastest reading times, but this difference was greater for the older group.

Regression analysis

In order to determine the separate contributions of age and WM on reading rate and comprehension, regression analyses were conducted. Reading rate and comprehension were used as dependent variables in separate analyses.

In the regression analysis for reading rate, age accounted for 31% of the variance in reading rate across Regions 2 and 3, $R = .585$, $F\ (2,39) = 10.16$, $p = .003$, and WM capacity accounted for 9% of the variance, $R = -.312$, $F\ (2,39) = 1.45$, $p = .24$.

In the regression analysis for reading comprehension, age accounted for 27% of the variance in comprehension across hyphenated and non-hyphenated sentences, $R = .527$, $F\ (2, 39) = 7.47$, $p < .001$, and WM accounted for 7% of the variance, $R = -.262$, $F\ (2, 39) = 1.69$, $p = .19$.

Discussion

In this self-paced reading task, designed to investigate the effect of hyphens on reading rate and reading comprehension of ambiguous (and non-ambiguous) sentences in younger and older participants, we see important advantages for hyphenating ambiguous phrases, especially for the older readers.

We had hypothesized that younger adults would read sentences containing ambiguous NPs faster and demonstrate more accurate comprehension than older adults generally. We further hypothesized that older readers, and perhaps younger ones as well, would demonstrate increased reading comprehension and faster reading speed for sentences with hyphenated ambiguous NPs than for those with non-hyphenated ambiguous NPs based on the rationale that the hyphens would constrain parsing of otherwise confusing *temporary compounds*, thus minimizing WM load.

Reading rate, not surprisingly, was fastest for the younger adults. They read faster across the three regions of both hyphenated and non-hyphenated sentences than older adults. On-line processing studies reveal that at important linguistic points in reading a sentence (e.g., key content words and phrase boundaries) the reader slows down (e.g., Boland, 2004; Kemper et al., 2004; Caplan, DeDe, Waters, Michaud, & Tripodis, 2011; Kemper & Herman, 2006). For this study, we can interpret the increased reading times of the non-hyphenated ambiguous NPs for both younger and older adults to mean that these structures are more complex to process than the hyphenated ambiguous NPs. Another possible explanation for this finding is that several meanings are activated and readers had to inhibit the incorrect ones, which is time-consuming. Reading times increase as well when sentences are disambiguated towards an unpreferred interpretation (Pickering, Traxler, & Crocker, 2000). Even though no unpreferred interpretations were created in the current study, a similar logic may be applied with the increased reading times for the hyphenated non-ambiguous NPs. Both younger and older readers demonstrated increased reading times for the hyphenated non-ambiguous NPs, possibly spending additional resources in processing these specific regions.

The relationship between reading times and linguistic structures is illustrated further by the on-line results of Region 3. For ambiguous sentences that were disambiguated by hyphens, reading times of Region 3 were fastest for younger and older readers. Contrastively, for sentences that remained ambiguous, reading times of Region 3 are slowest for both groups of readers. These on-line processing data are consistent with those of studies investigating reading times of materials following ambiguous segments. For example, Rumelhart (1984) demonstrated that readers not only slowed down at important linguistic points in reading a sentence, they also were then slowed down in reading the materials that follow unresolved ambiguous segments. Similarly, Mohamed and Clifton Jr. (2011) demonstrated that reading times can be affected negatively for regions following an unresolved or forced ambiguity. Our data support the fact that unresolved ambiguities slow down readers in the materials following the ambiguous segments, whereas disambiguated segments (i.e. hyphenated ambiguous NPs) result in decreased reading times in the following segments. The results also indicate that hyphens can affect the comprehension of ambiguous sentences that contain *temporary compounds*. Younger and older adults demonstrated more accurate comprehension when a *temporary compound* was disambiguated with a hyphen. These results are compatible with a study (Kemper et al., 1993), where reading comprehension was facilitated by reducing the syntactic complexity of the reading material by reducing the number of embedded clauses.

In the same study, Kemper et al. (1993) reported that comprehension measures for younger readers did not evidence sensitivity to sentence (or paragraph) complexity. However, the older adults' reading comprehension showed a decrease with an increase of text complexity. Similarly, the reading accuracy data for older participants from our study did demonstrate significant differences across hyphenated and non-hyphenated sentences, whereas younger participants showed little variation in Yes/No question accuracy for the hyphenated and non-hyphenated conditions. The significant interaction of age and hyphenation indicates that older adults benefitted relatively more than younger adults when ambiguous phrases were disambiguated by hyphens.

This facilitatory effect, i.e., shorter reading times with disambiguating hyphens in ambiguous phrasing, becomes most evident with the results from the non-ambiguous sentences where a hyphen was added. Recall that the non-ambiguous sentences where a hyphen was added were consistently read slower than those in which no hyphen was present in both presentation conditions in both participant groups. As well, the comprehension accuracy of this set of items was lower for both groups than the non-ambiguous items without hyphens. The lower reading comprehension accuracy following non-ambiguous sentences where a hyphen was added may suggest that unnecessary hyphens can confuse all readers and thus interfere with comprehension.

Whereas the benefit of hyphens, especially for older adults, was predicted, the minor role played by WM capacity in this task was not. One explanation for these results may be the relatively low WM load, for either processing or storage, required to process the experimental structures of this study. The experimental sentences for this study were chosen to approximate those that would be encountered in everyday reading, and did not resemble the typical syntactically complex sentences of other psycholinguistic studies. The role of WM has been closely associated with the processing of syntactically complex sentences for structures such as the commonly studied object relative sentence structures (e.g., King & Just, 1991; Vos et al., 2001). By contrast, we were testing more local, phrase-structure syntax which, one could argue, may not burden WM so highly. As Grossman et al. (2002) observe, it is the storage capacity of the WM resources that decreases with age, not the processing capacity.

Another possibility is that the common findings linking WM to comprehension are in fact masking the importance of other linked cognitive skills that have been demonstrated to change with advancing age, namely processing speed and inhibition. Borella, Ghisletta, and Ribaupierre (2011) point out that many studies investigating the relationship between aging, language comprehension, and WM (e.g., DeDe et al., 2004) do not include measures of processing speed or inhibition. In agreement with other researchers (e.g. Hasher, Lustig, & Zacks, 2007), they argue that reduced inhibition and processing speed may render older readers less efficient in language processing which will overload WM capacity sooner.

Indeed, we have some indication that distraction may contribute to older adults' performance on our task, in their poorer performance on the hyphenated non-ambiguous phrases. In an eye-tracking study, Kemper et al. (2008) demonstrated that older readers spent as much processing capacity on both target and distractor words as the younger readers. The authors argued that the younger adults spent their resources on reading and trying to understand the distractor words, whereas the older participants spent their resources reading the sentences as "word lists" and did not attempt to fully understand the sentences. Our data suggest that the older adults may be more easily distracted by the *temporary compounds* than the younger adults. This is especially evident both when ambiguous *temporary compounds* do not have hyphenation added and when non-ambiguous hyphenated *temporary compounds* do.

In summary, the present study suggests a new way that we can facilitate reading for older adults (and for anyone else for whom reading is important but challenging). The value of hyphens to disambiguate potentially ambiguous structures demonstrated in this study, may have its most effective application in texts with novel words and phrases concerning terms that are relatively unfamiliar for older readers (e.g. health-care materials, instructions for electronic equipment and the like). Kemper et al. (1993) demonstrated that reducing the number of relative clauses increased comprehension of medical insurance instructions in older participants; our study demonstrated that hyphenation should be used in preparing reading material that is complex by virtue of its triple-noun compounds. The combination of two techniques, e.g., reduction of relative clauses in addition to hyphenation in ambiguous phrasing, should result in even greater increases in reading facilitation. To more fully determine which factors facilitate reading for older individuals, we recommend that future research combine such techniques.

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