Published in final edited form as:
*Psychol Aging*. 2012 September ; 27(3): 638–649. doi:10.1037/a0026540.

# Aging, Parafoveal Preview, and Semantic Integration in Sentence Processing: Testing the Cognitive Workload of Wrap-up

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## Abstract

The current study investigated the degree to which semantic integration processes (“wrap-up”) during sentence understanding demand attentional resources by examining the effects of clause and sentence wrap-up on the parafoveal preview benefit in younger and older adults. The parafoveal preview benefit (PPB) is defined as facilitation in processing word N+1 based on information extracted while the eyes are fixated on word N, and is known to be reduced by processing difficulty at word N. Participants read passages in which word N occurred in a sentence-internal, clause-final, or sentence-final position and a gaze-contingent boundary change paradigm was used to manipulate the information available in parafoveal vision for word N+1. Wrap-up effects were found on word N for both younger and older adults. Early pass measures (first fixation duration and single fixation duration) of the PPB on Word N+1 were reduced by clause wrap-up and sentence wrap-up on word N, with similar effects for younger and older adults. However, for intermediate (gaze duration) and later pass measures (regression path duration, and selective regression path duration), sentence wrap-up (but not clause wrap-up) on word N differentially reduced the PPB of word N+1 for older adults. These findings suggest that wrap-up is demanding and may be less efficient with advancing age, resulting in a greater cognitive processing load for older readers.

## Keywords

reading; sentence processing; parafoveal preview; eye-tracking

Consistent with the idea that aging has its largest negative impact on fluid abilities, which place heavy demands on attentional processes, age deficits are most pronounced in aspects of language comprehension that are highly effortful. For example, while automatic and obligatory processes, such as visual word-recognition, tend to show relative age invariance (Laver & Burke, 1993; Spieler & Balota, 2000), older adults do have reliably worse memory for text (Johnson, 2003) and show reduced efficiency in processing propositionally dense content (Hartley, Stojack, Mushaney, Annon, & Lee, 1994; Stine & Hindman, 1994). Collectively, these findings suggest that the ability to retain message-level semantics show

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some age-related declines. However, the mechanisms underlying these effects are not well understood.

One potential mechanism that has been associated with online organizational and integrative semantic processing during reading is a phenomenon called *wrap-up*. Wrap-up effects, which are characterized by a relative increase in processing time at clause and sentence boundaries, are robust in the literature (Aaronson & Scarborough, 1976, 1977; Ditman, Holcomb, & Kuperberg, 2007; Haberlandt & Graesser, 1989; Hill & Murray, 2000; Hirotani, Fraizer, & Rayner, 2006; Just & Carpenter, 1980; Millis & Just, 1994; Miller & Stine-Morrow, 1998; Payne, Gao, Noh, Anderson, & Stine-Morrow, in press; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989; Rayner, Kambe, & Duffy, 2000; Smiler, Gagne, & Stine-Morrow, 2003; Stine, 1990; Stine-Morrow, Millinder, Pullara, & Herman, 2001; Stine-Morrow, Miller, Gagne, & Hertzog, 2008; Stine-Morrow, Shake, Miles, Lee, Gao, & McConkie, 2010; Warren, White, & Reichle, 2009; Waters & Caplan, 2001) and have been related to subsequent memory performance (Haberlandt, Graesser, Schneider, & Kiely, 1986; Miller & Stine-Morrow, 1998; Stine, 1990; Stine-Morrow et al., 2008) in both younger and older adults. At the same time, there is some controversy about the nature of this effect.

## Wrap-up Effects During Reading: Dwell-Time vs. Semantic Integration Views

Though a number of studies have collectively shown that readers allocate more time at clause and sentence boundaries, it is not exactly clear why this is the case. A review of the literature suggests that there exist two contrasting explanations for wrap-up. One viewpoint, which we call the dwell-time view after Hirotani et al. (2006), argues that wrap-up is an automatic and obligatory process that is driven by low-level mechanisms, such as a hesitation response to punctuation or to the implicit monitoring of intonational contour (Hill & Murray, 2000; Hirotani et al., 2006). Under this view, wrap-up need not be related to demanding semantic processing (Hirotani et al., 2006). A second viewpoint, which we call the semantic integration view, suggests that these peaks in reading time at clause and sentence boundaries are due to a process in which semantic information is integrated across clauses and sentences (Just & Carpenter, 1980; Rayner et al., 2000). Under this view, this increased processing time is associated with the binding and integration of information in the course of the cyclical input of text (Kintsch & van Dijk, 1978). In contrast to the dwell-time view, the semantic integration account suggests that wrap-up is a resource-demanding process.

Evidence consistent with the dwell-time view comes from studies suggesting that wrap-up effects may manifest as an oculomotor hesitation response to punctuation during reading (Hill & Murray, 2000). Similarly, Hirotani et al. (2006) examined the effects of punctuation on eye-movements during reading, focusing on comma placement at boundary sites that correspond to intonational phrase boundaries in speech. They argued that because semantic and syntactic analysis is incremental, it is not clear what incomplete work is left to be done at the end of clauses and sentences. They proposed the dwell-time account, in which wrap-up is related to punctuation and the monitoring of the intonational properties of the sentence and “need not be related to the amount of work to be done at the clause boundary” (Hirotani et al., 2006, p. 426). In line with the dwell time view, they found evidence for wrap-up at brief unambiguous clauses and at the end of phrase boundaries such as vocatives (i.e., *John*, go to the library for me). They also found evidence that the magnitude of wrap-up effects did not differ as a function of sentence length. Similarly, Warren, White, and Reichle (2009) found that wrap-up did not vary as a function of syntactic complexity.

Evidence consistent with the semantic integration view comes from studies finding that text demands related to semantic processing influence the wrap-up effect (Daneman & Carpenter, 1983; Haberlandt et al., 1986; Haberlandt & Graesser, 1989; Stine, 1990). For example, Haberlandt and Graesser (1989) found that reading time at clause and sentence boundaries differentially increased as a function of the number of new argument nouns introduced in the sentence and Daneman and Carpenter (1983) showed that ambiguity resolution processes influenced the magnitude of wrap-up effects. At the same time, increased clause wrap-up is related to reduced downstream processing (Stine-Morrow, Shake, et al., 2010), and the magnitude of the wrap-up effect is moderated by prior text knowledge (Miller & Stine-Morrow, 1998; Sharkey & Sharkey, 1987; Wiley & Rayner, 2000), and varies as a function of individuals' literacy habits (Payne et al., in press; Stine-Morrow et al., 2008). Additionally, event-related brain potential studies of sentence reading have revealed that larger wrap-up effects in self-paced reading are associated with greater N400 amplitudes (Ditman et al., 2007) and that introducing semantic and syntactic anomalies in sentence-internal positions results in a larger N400 component at the sentence-final position, suggesting that there are downstream semantic consequences of encountering anomalies earlier in a sentence (Hagoort, 2003).

Interestingly, there are adult age differences in wrap-up that often have an appreciable influence on subsequent text recall. In self-paced reading, younger adults sometimes show larger wrap-up effects and better memory performance (e.g., Stine, 1990), suggesting that older adults may not allocate extra processing resources at the ends of sentence boundaries, and as a result, memory performance is poorer. However, when older adults show comparable sentence memory performance to younger adults, older adults have invariably allocated extra processing time to wrap-up (Miller & Stine-Morrow, 1998; Stine-Morrow et al., 2001; Smiler, et al., 2003; see Stine-Morrow, Miller, & Hertzog, 2006 for a review). Further evidence for a causal link between wrap-up and sentence recall comes from an experiment in which younger and older adults were given explicit instruction in conceptual integration during reading (Stine-Morrow, Noh, & Shake, 2010). Results showed that wrap-up increased as a function of instruction and that changes in wrap-up produced improved recall.

Thus, older readers can be highly variable in allocating time to wrap-up, though when they do, they show comparable text memory to younger adults. However, older adults do not always engage in this apparently compensatory strategy. Under the semantic integration viewpoint, one reason this might be the case is that wrap-up is a more demanding process for older readers. Therefore, the aim of the current study was to test the degree to which wrap-up is resource-consuming for younger and older adults. If wrap-up is demanding, it should produce a greater cognitive workload (Just, Carpenter, & Miyake, 2003) at clause and sentence boundary sites, reducing the parafoveal processing of words that immediately proceed clause and sentence boundaries (cf. Henderson & Ferreria, 1990).

## Parafoveal Processing and the Preview Benefit as an Index of Cognitive Workload

The perceptual span is the field of useful information that can be processed during a given fixation (McConkie & Rayner, 1975) and ranges from 3–4 characters to the left of fixation to about 14–15 characters to the right of fixation for readers of English (McConkie & Rayner, 1975, Miellet, O'Donnell, & Sereno, 2009; Rayner & Bertera, 1979). Because the perceptual span extends asymmetrically, it is typical for the word to the right of fixation to be partially processed before the saccade to that word.

A number of eye-tracking paradigms have been developed in order to study the perceptual span and parafoveal preview benefit during reading. In the boundary change paradigm (Rayner, 1975), an invisible boundary is placed between word N and word N+1. The eyes crossing the boundary triggers a change in the display, which can be used to manipulate the availability of parafoveal information on word N+1. On selected trials, word N+1 is initially replaced by a non-word or mask that provides no valid cues about word N+1 other than length. As the reader saccades from word N to word N+1, the mask is replaced with the actual target word N+1. If a reader typically obtains parafoveal information from word N+1 while fixating word N, any inconsistency between what is available parafoveally (before the change) and what is available when fixating word N+1 (after the change) results in an increase in processing time. A number of studies using this paradigm have demonstrated a characteristic *parafoveal preview benefit*: when the reader received a valid preview of word N+1, reading times on that word are 30–50 ms shorter relative to trials in which word N+1 was initially replaced with a mask (see Rayner, 1998, 2009 for reviews).

Importantly, a number of studies have demonstrated that the parafoveal preview benefit varies as a function of both text difficulty (Henderson & Ferreria, 1990; White, Rayner, & Liversedge, 2005), and reading ability (Rayner, 1986; Chace, Rayner & Well, 2005). For example, Henderson and Ferreria (1990) manipulated the frequency of word N and the availability of parafoveal preview on word N+1 and demonstrated that, when word N was low in frequency, the parafoveal preview benefit on N+1 was greatly reduced compared to when word N was frequent (see also, White, Rayner, & Liversedge, 2005). In a second experiment, they replicated this effect with syntactic complexity, showing that the preview benefit was reduced when word N was a syntactically disambiguating word in a garden path sentence. Collectively, these findings suggest that, while there are biological and perceptual limitations on the useful field of vision during reading, the preview benefit is not completely biologically hardwired, as attentional and cognitive factors do constrain the size of the perceptual span.

While a number of studies have examined individual differences in the perceptual span and preview benefit (Chace et al., 2005; Kennison & Clifton, 1995; Rayner, 1986; Rayner, Slattery, & Bélanger, 2010), only very recently have age differences been examined. Rayner, Castelhano, and Yang (2009) investigated the size and symmetry of the perceptual span in younger and older readers using a gaze-contingent moving window paradigm. They found that, while older adults showed a reduced asymmetry in the perceptual span, they still obtained useful parafoveal word information from the word to the right of fixation. Further, Rayner, Castelhano and Yang (2010) used a gaze-contingent boundary change paradigm and found that older adults showed a significant preview benefit in early-pass measures (i.e., first fixation duration and single fixation duration), but for intermediate and later-pass measures (i.e., gaze duration, regression path duration), older adults showed an attenuated preview benefit. The authors argued that the age-related attenuation of the preview benefit was localized to particular trials where target words were refixated and re-read, suggesting that the age differences manifested primarily in trials where processing difficulty was greater. Lastly, Risse and Kliegl (2011) showed that, similar to younger adults (Kliegl et al., 2007)[1], older adults did show a significant preview benefit for word N+2 (when word N+1 was three characters long), suggesting that they were able to extract orthographic information from words with greater visual eccentricity. Overall, these few studies suggest that, while there may be some age-related declines in parafoveal processing (particularly in

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[1] The question of whether readers obtain a preview benefit from word N+2 is currently a highly controversial issue in the literature (see Rayner, 2009 for a review), as a number of studies have failed to find such effects (Angele & Rayner, 2011; Angele, Slattery, Yang, Kliegl, & Rayner, 2008; Rayner, Juhasz, & Brown, 2007).

cases when text demands are high) older adults are able to extract information from the word to the right of fixation in parafoveal vision during normal reading.

## The Current Study

We had two major goals in the current study. First, we took advantage of the boundary change paradigm to test the notion that wrap-up increases cognitive workload by examining the degree to which clause and sentence wrap-up effects on word N influence the magnitude of the preview benefit on word N+1. If wrap-up is resource-consuming, then the preview benefit should be expected to be reduced across clause and sentence boundaries. However, if wrap-up is purely an index of a low-level pause or dwell response, then there should not be any attenuation of the amount of information that can be extracted from word N+1 across clause and sentence boundaries and thus, there should be no differences in the magnitude of the preview benefit as a function of the position of word N.

Secondly, we wanted to test the idea that the workload of wrap-up is more resource consuming for older readers by examining age differences in the effect of clause and sentence wrap-up on the preview benefit. Some studies (e.g., Stine-Morrow et al., 2001) suggest that older readers have to expend more effort in order to achieve effective semantic integration. However, Caplan and Waters (1999; Waters & Caplan, 1996, 2001; Caplan, Gayle, Waters, Michaud, & Tripodis, 2011) have argued that there exists a separate language interpretation resource used during online language processing that is not depleted by factors, such as age, that cause declines in working memory. If the cognitive workload associated with wrap-up is particularly demanding for older adults, then the magnitude of the preview benefit would be expected to be reduced by wrap-up to a greater degree for older adults compared to younger adults. However, under a separate language resource view (Caplan & Waters, 1999) there should be no age differences in online processing as a function of text difficulty.

## Methods

### Participants

Participants were 24 younger adults ($M_{age}$ = 20.87, $SE$ = .57; Range = 18–29) and 22 older adults ($M_{age}$ = 68.36, $SE$ = 1.28; Range = 61–84). An additional three younger and two older adults were excluded from the analysis (see *Analysis* section for details). Younger adults were undergraduate students and older adults were volunteers from the local community. Participants received either course credit or $10 remuneration for their participation in the experiment. Individuals were native speakers of English; reported no history of any major health concerns or neurological impairments; rated their health, vision, and hearing as good or excellent; and had at least 20/30 corrected vision.

### Apparatus

Sentences were presented on a 19-in. ViewSonic P225f monitor set to a resolution of 1,024 × 768, with a refresh rate of 120 Hz. Two Dell 3.20 GHz computers controlled the eye-tracking system. An SR Research Eye-Link II (Ontario, Canada) head mounted eye-tracking system monitored gaze location of the participant’s right eye. The head-mounted eye tracker sampled at a rate of 500 Hz. The instructions and passages were displayed in a white, TrueType non-proportional font (Courier New, size 16) on a black background. Participants were seated approximately 96.5 cm from the monitor, such that three letters subtended about 1 degree of visual angle. While most sentences were longer than 80 characters, and as such, did not fit on one line, both the target and post-target word always occurred before the end of the first line.

### Materials and Design

Materials included 36 experimental items (and an additional 24 filler items, and five practice items). Word position (sentence-internal, clause-final, sentence-final) and parafoveal preview (valid preview, invalid preview) were factorially combined to create six experimental conditions. An example set is presented below, where word N (in *italics*) is in the sentence-internal (1a), clause-final (1b), and sentence-final (1c) position. Target word N +1 is underlined and the invalid preview condition is shown in parentheses.

**(1a)** After the children watered the baby oak *tree* <u>(fcrg) next</u> to the house, they could go play.

**(1b)** After the children watered the baby oak *tree*, <u>(fcrg) next</u> on their list was watering the garden.

**(1c)** The children had watered the baby oak *tree*. <u>(Fcrg) Next</u> on their list was watering the garden.

For each stimulus set, words N and N+1 were always the same across conditions, and sentences were kept as similar as possible across the word position condition. The sentence-internal and clause-final conditions were identical up through words N and N+1. In the sentence-final condition, sentences were either identical or nearly identical to the sentence-internal and clause-final conditions through words N and N+1. For word N +1, the invalid preview was always a random string of visually dissimilar consonants of the same length as the preview word. These consonant strings were generated at random from the MCWord orthographic word-form database (Medler & Binder, 2005). If any of the first 4 characters of the invalid preview matched or were visually similar to the first 4 characters of the word preview for that condition, those characters were changed. This was done in an effort to produce the largest preview benefit (see Henderson & Ferreria, 1990). The distance between word N and N+1 was kept constant across the word position conditions so that the clause-final and sentence-final conditions were not confounded with any increase in visual eccentricity of word N+1 (which would inherently decrease the parafoveal preview benefit), compared to the sentence-internal condition. Therefore, any word position effects could not be attributed to the extra character spacing.

In the sentence-internal condition, words N, N+1, and N+2 always appeared in sentence-internal positions. In the clause-final condition, word N always appeared at a comma-marked clause boundary and word N+1 was the first word of the following clause. In the sentence-final condition, word N always appeared in the sentence-final position and word N +1 was the first word of the following sentence. Word N was between 4 and 8 letters long ($M = 5.69$) and word N +1 was between 4 and 8 letters long ($M = 6.13$). Word frequency was estimated from the Hyperspace Analogue to Language (HAL) frequency norms available through the English Lexicon Project (Balota et al., 2007). The natural log word frequency ranged between 7 and 12 ($M = 9.56$) for word N and between 7 and 15 for word N +1 ($M = 10.89$).

Six counterbalanced lists were constructed, following a Latin square design. Sentences were presented in one fixed but random order. Simple yes/no questions were asked on one third of the trials to ensure that the participants were reading for comprehension.

### Procedure

The experimental session lasted 60 to 90 min. After participants completed a brief demographic questionnaire, they were seated in front of the presentation computer for the eye-tracking portion of the experiment. Participants placed their heads in a chinrest to minimize head movements and were fitted with the head-mounted eye tracker. After the tracker was aligned and calibrated, the participants began the practice and experimental trials. A fixation correction was presented between each trial in order to check that the system was still correctly calibrated. In cases where a minor drift occurred, the system auto-corrected before the beginning of the trial. In cases where calibration was lost, the system was completely recalibrated before moving forward. A gaze-contingent boundary change paradigm (Rayner, 1975) was used to manipulate the parafoveal word information on word N+1. The invisible boundary was placed between the penultimate and final letter of word N (see Henderson & Ferreira, 1990). The average delay between the boundary trigger and the display change was 12 ms (Range = 9 – 18 ms). Lastly, participants were administered a brief battery of individual difference measures and a debriefing interview that probed their awareness of the display change.

## Analysis

Participants who explicitly noticed the boundary change and reported seeing three or more display changes were not included in the analysis (N = 3). Additionally, two participants were excluded from analysis due to technical problems during recording. Of the remaining participants ($N_Y = 24$; $N_O = 22$), fixations that were less than 80 ms and fell within a half degree of visual angle were incorporated into one fixation. Remaining fixations less that 80 ms and greater than 1,000 ms were discarded from data analyses. Trials were also discarded in which a blink occurred on word N or N+1 or on trials where N or N+1 were not initially fixated. All trials were discarded in which a display change did not complete within the latency of the forward moving saccade to N+1 that triggered the display change (i.e., the display did not change by the start of the first fixation on word N+1). Overall, this data trimming procedure resulted in 19.3% of the experimental trials being excluded from analyses for younger adults and 20.4% of the trials for older adults, which is on par with other studies using the boundary change paradigm (see Chace et al., 2005; Hyönä et al., 2004; White et al., 2005). Missing data were distributed evenly across conditions[2].

Analyses on the fixation time measures were conducted using linear mixed effects models (Snijders & Bosker, 1999; Baayen, Davidson, & Bates, 2008), with subjects and items specified as crossed random effects. Dichotomous outcomes (e.g., probability of regressing out, probability of refixation) were analyzed using generalized logit mixed models with subjects and items as crossed random effects. SAS Proc Mixed (Version 9.2) was used to fit the linear mixed effects models and SAS Proc GLIMMIX (Version 9.2) was used to fit the logit mixed models[3]. All models were based on maximum likelihood estimation. Significance tests for fixed effects were conducted using likelihood ratio tests (Agretsi, 2002; Jaeger, 2008; Snijders & Bosker, 1999; Verbeke & Molenberg, 2000). This test statistic is calculated as the difference between −2 times the log likelihood for a full model and a nested model (without the predictor being tested) and follows an approximate $\chi^2$ distribution with degrees of freedom (*df*) equal to 1 (i.e., the difference in parameters between the full and nested models).

Across all analyses, there was significant variability across both subjects and items. Age and preview were specified as fixed effects, as were two contrasts for word position, which represented the clause wrap-up effect (sentence-internal vs. clause final) and the sentence

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[2] The skipping rate was 14% for word N and 12% for word N+1. For word N, there was a marginal age difference in skipping rate ($p = .09$), with older adults showing a higher probability of skipping word N (17%) than younger adults (11%). For word N+1, there was a significant effect of clause wrap-up ($p = .04$), such that word N+1 was more likely to be skipped if word N was sentence internal (15%) compared to when word N was clause final (10%). No other effects reached significance (all $p$'s > .27).

[3] By assessing variance associated with both subjects and items simultaneously, linear and generalized linear mixed effects models allow the researcher to perform all statistical analyses within a single model, avoiding the need for separate F1 (subject) and F2 (items) repeated measures ANOVAs. In addition to increased power, these models are also robust against missing data (Baayen et al., 2008), a benefit for eye-tracking paradigms such as the one in the current study.

wrap-up effect (sentence-internal vs. sentence-final). When there were significant interactions between preview and either wrap-up contrast, we decomposed these interactions in follow-up analyses by examining a priori contrasts of interest (i.e., the effect of preview at conditional levels of word position). Likewise, when age was a significant moderator (in two-way and three-way interactions), these comparisons were explored in follow-up analyses by fitting age-separate models.

## Results

Several standard fixation measures were calculated for words N and N+1. Two early-pass measures, single fixation duration (SFD) and first fixation duration (FFD) are reported. SFD is the duration of the first fixation on a word on trials where only one first-pass fixation was made on the word. FFD is the duration of the first fixation on a word, regardless of whether it was also re-fixated. Single fixation duration and first fixation duration are often referred to in the literature as early measures, because they are thought to reflect first-pass processing and are often more sensitive to lower-level, lexically driven processes than they are to higher-level processes (see Clifton, Staub, & Rayner, 2007; Staub & Rayner, 2007 for discussions). Gaze duration (GD), which is the sum of all first-pass fixations on a word before the eyes move to another word, is also reported. GD has also been referred to as an early-pass measure, similar to FFD and SFD, but is considered a more intermediate measure of processing, since it does include variance from first-pass refixation durations within a word, which likely reflect sources of interference in normal processing.

Later-pass measures included regression path duration (also called go-past time) and selective regression path duration. Regression path duration (RPD) includes the sum of all fixations from when a reader first enters the target word, including the time spent re-fixating earlier words, until he or she moves past the target word to the right. Selective regression path duration (sRPD), by contrast, includes all initial fixations as well as refixations on the target word following regressions back to earlier words in the sentence. Unlike RPD, this measure only includes fixation durations on the target word itself, and not the time spent re-fixating earlier words in the sentence. Because RPD includes re-fixation time to non-target words to the left of N+1, sRPD is arguably a more sensitive measure of effects on the preview benefit than RPD, especially considering that the locus of effects in sRPD are isolated to word N+1. These latter two measures have been used to index temporally later occurring processes since they include durations after first-pass fixations. A direct correspondence of the distinction between early and late eye-movement measures with the distinction between early and late stages of cognitive processes is no doubt an oversimplification. However, effects that appear only in early measures are more likely to index earlier automatic and obligatory processes while effects that manifest only in intermediate or later measures are more likely to reflect temporally slower processes or later stages of cognitive processes (Clifton et al., 2007; Inhoff, 1984).

Although temporal measures are more sensitive to cognitive processing factors (Staub & Rayner, 2007), saccade-based measures often reveal important effects in eye-movement control during reading. Therefore, we also report two non-temporal measures of eye movements: the proportion of trials in which a regression was launched from both word N and word N+1 and the proportion of trials in which there was a first-pass refixation on word N+1.

### Effects on Word N

Table 1 shows the mean fixation times for word N and the proportion of regressions out of word N as a function of Age and Word Position. Word N was fixated for significantly longer in the clause boundary position compared to when it occurred in the sentence-internal position, $\chi^2(1)_{FFD} = 8.25$, $p < .01$; $\chi^2(1)_{SFD}$, = 8.07, $p < .01$; $\chi^2(1)_{GD} = 9.17$, $p < .01$; $\chi^2(1)_{RPD} = 7.45$, $p < .01$; $\chi^2(1)_{sRPD} = 7.77$, $p < .01$. Similarly, when word N was at a sentence boundary, it was fixated for significantly longer than when it occurred in the sentence-internal position, $\chi^2(1)_{FFD} = 14.97$, $p < .001$; $\chi^2(1)_{SFD}$, = 12.01, $p < .001$; $\chi^2(1)_{GD} = 18.30$, $p < .001$; $\chi^2(1)_{RPD} = 18.36$, $p < .001$; $\chi^2(1)_{sRPD} = 18.47$, $p < .001$. The only significant age interaction was a reliable Age X Sentence Wrap-up effect for single fixation duration, $\chi^2(1) = 6.68$, $p < .01$, such that younger adults (31 ms) showed a comparably longer sentence wrap-up effect in SFD than older adults (12 ms). There were no other significant interactions between Age and Word Position (all *p’s* > .17). The probability of launching a regression out of word N was greater if it appeared in the sentence-final position versus when it appeared in the sentence-internal position, $\chi^2$ (1) = 13.56, $p <. 001$. No other effects significantly predicted the probability of regressing out of word N (all *p*’s > .35). Collectively, these findings showed that there were reliable clause and sentence wrap-up effects at word N for both younger and older adults.

There was a main effect of preview on word N in GD, $\chi^2$ (1) = 8.68, $p < .01$, such that when the N+1 preview was invalid, gaze durations were about 20 ms longer than when the N+1 preview was a valid word in the parafovea. This is consistent with some studies that have found evidence for an orthographic parafoveal-on-foveal effect, suggesting that the orthographic familiarity of initial letter sequences of words in parafoveal vision can affect processing on the currently fixated word (see Rayner, 2009 for a discussion). No other effects of Preview on word N were significant, nor were any interactions between Preview, Word Position, or Age for SFD (all *p*’s > .36), FFD (all *p’s* >.15), RPD (all *p’s* >.43), sRPD (all *p’s* >.19), or the proportion of regressions out of word N (all *p*’s >.31)[4].

## Early Effects on Word N+1

The first two rows of Table 2 show the fixation time data for first fixation duration and single fixation duration for word N+1. The main effect of Preview was significant, revealing the classic preview benefit effect, $\chi^2_{FFD}$ (1) = 8.07, $p < .01$; $\chi^2_{SFD}$ (1) = 10.53, $p < .001$. That is, words with an initial invalid preview ($M_{FFD} = 250$ ms; $M_{SFD} = 253$ ms) were fixated for significantly longer than those with a valid preview ($M_{FFD} = 223$ ms; $M_{SFD} = 228$ ms).

Importantly, the Clause Wrap-up X Preview interaction was significant, $\chi^2_{FFD}$ (1) = 5.76, $p = .02$; $\chi^2_{SFD}$ (1) = 3.69, $p = .05$, suggesting that wrap-up moderated the size of the preview benefit. Examining the effect of preview at conditional levels of word position revealed that the preview benefit (invalid preview – valid preview) in the sentence-internal condition was 41 ms in FFD, $\chi^2$ (1) = 23.02, $p < .0001$ and 43 ms in SFD, $\chi^2$ (1) = 20.04, $p < .0001$, but in the clause-final position, the preview benefit was only 17 ms in FFD, $\chi^2$ (1) = 5.71, $p = .02$, and 14 ms in SFD, $\chi^2$ (1) = 2.42, $p = .12$. The Sentence Wrap-up X Preview interaction did not reach significance for FFD, $\chi^2$ (1) = 2.10, $p = .14$, but was marginally significant for SFD, $\chi^2$ (1) = 3.04, $p = .08$. In the sentence-final position, the preview benefit was 23 ms for FFD, $\chi^2$ (1) = 7.20, $p < .01$, and 17 ms for SFD, $\chi^2$ (1) = 4.35, $p < .04$. Neither the Clause Wrap-up X Preview nor the Sentence Wrap-up X Preview effects interacted with age for SFD or FFD (all *p’s* > .60) and no other effects reached significance.

Thus, in the earliest first-pass measures of processing, there was evidence that clause wrap-up reduced the size of the preview benefit similarly for both younger and older readers. It is important to note that, while the preview benefit was reduced by wrap-up, it was still

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[4] Although there were few local main effects (i.e., restricted to word N or N+1) of age, across the entire sentence, older adults had a significantly longer FFD, GD, RPD, and sRPD than younger adults (all *p*’s < .01).

significantly different from zero for each word position, with the exception of SFD in the clause-final position, indicating that readers still received at least some benefit in lexical processing from the parafoveal preview in all word positions.

### Intermediate and Late Effects on Word N+1

Figure 1 plots the effects of age and wrap-up on the preview benefit on word N+1 for GD, RPD, and sRPD. To preview the results, in contrast to the early-pass measures, each of the three later-pass measures revealed significant age differences in the effects of wrap-up on the preview benefit. While younger adults showed a significant preview benefit that did not differ as a function of word position, older adults showed a systematic reduction in the preview benefit as a function of demands for semantic integration, such that sentence wrap-up completely eliminated the parafoveal preview benefit as measured by GD, RPD, and sRPD.

**Gaze duration—**The third row of Table 2 shows the fixation time data for gaze duration for word N+1. The main effect of preview was significant, such that words with an invalid parafoveal preview ($M = 298$ ms) were fixated longer than those with a valid preview ($M = 264$ ms), $\chi^2$ (1) = 6.62, $p < .05$. However, the Sentence Wrap-up X Preview X Age interaction was significant, $\chi^2$ (1) = 5.17, $p = .02$, indicating that the size of the preview benefit in GD was diminished by sentence wrap-up among older readers but not younger readers, as evident in the top panel of Figure 1[5]. Fitting age separate models did reveal that there was a robust Sentence Wrap-up X Preview interaction among the older adults, $\chi^2$ (1) = 13.21, $p < .001$, but not among the young, $\chi^2$ (1) = .08. The Clause Wrap-up X Preview X Age interaction was not significant, $\chi^2$ (1) = .12. Examining the effect of preview at conditional levels of sentence position revealed that, for younger adults, the preview benefit was reliable across each sentence position. For older adults, however, there was a significant preview benefit of 64 ms in the sentence-internal condition, $\chi^2$ (1) = 13.01, $p < .001$, and a significant preview benefit of 47 ms in the clause-final condition, $\chi^2$ (1) = 8.82, $p < .01$, but there was not a significant preview benefit in the sentence-final condition among older adults, with a comparison of the invalid and valid preview conditions yielding a difference of −19 ms, which was not significantly different from zero, $\chi^2$ (1) = 2.40, $p > .10$. No other effects reached significance in GD.

The findings from the analysis on gaze durations suggests that the size of the preview benefit was constrained by sentence wrap-up but that this effect was only found among older adults, who received no parafoveal preview benefit for words at the beginning of sentences, presumably due to the increased processing load associated with sentence wrap-up.

**First-pass Refixations—**Because of the differences between the early pass measures (SFD and FFD) and GD, we also examined first-pass refixations ("refixations" from here on) on word N+1, with the logic being that any differences between FFD and GD would be driven by differences in either the proportion of refixations or in the duration of refixations on word N+1 (Reingold, Yang & Rayner, 2010; Rayner et al., 2010). The sixth row of Table 2 shows the refixation data for word N+1. Overall, refixations on word N+1 occurred on

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[5] The Sentence Wrap-up X Preview interaction was significant, indicating that the preview benefit was moderated by sentence wrap-up, $\chi^2$ (1) = 6.54, $p = .01$, but not by clause wrap-up, as the Clause Wrap-up X Preview interaction was not reliable, $\chi^2$ (1) = .55, $p > .10$. Examining the effect of preview at conditional levels of sentence position revealed that there were significant preview benefits of 53 ms in the sentence-internal condition, $\chi^2$ (1) = 16.79, $p < .001$, and 42 ms in the clause-final condition, $\chi^2$ (1) = 16.20, $p < .001$, but there was no evidence of a significant preview benefit in the sentence-final condition, with a difference between the invalid preview and valid preview conditions of only 8 ms, which was not different from zero, $\chi^2$ (1) = .34. However, the significant higher order interaction with age revealed that this effect was entirely driven by performance of the older group.

22% of the trials, across all conditions. Examining the proportion of trials with refixations on word N+1 as a function of age, preview, and word position revealed two reliable effects.

The first significant effect that was found was the Sentence Wrap-up X Preview interaction, $\chi^2$ (1) = 9.94, $p < .01$. This was due to readers showing a reliable preview benefit for sentence-internal words, $\chi^2$ (1) = 4.01, $p = .04$, but showing an opposite effect for sentence-final words, with readers actually re-fixating words in the invalid preview condition marginally less than in the preview condition, $\chi^2$ (1) = 3.58, $p = .06$. The second significant effect was the Sentence Wrap-up X Preview X Age interaction, $\chi^2$ (1) = 4.64, $p = .03$, which suggested that the above effects were driven by the older adults. That is, the Sentence Wrap-up X Preview interaction was reliable for older adults, $\chi^2$ (1) = 10.39, $p < .01$, but not for the young, $\chi^2$ (1) = .05.

Thus, it appears that one of the underlying reasons that there were differences between the early-pass measures and GD among older adults was that there were differences in the proportion of refixations on word N+1 in the valid and invalid preview conditions. Specifically, in the sentence-internal and clause-final positions, words in the invalid preview condition were refixated more often than those in the valid preview condition, which was not the case in the sentence-final condition[6]. To the extent that the increased rate of refixations on word N+1 in the invalid preview condition reflect difficulty in integrating invalid parafoveal word information across saccades, the finding that this effect was reduced in the sentence-final condition suggests that sentence wrap-up may have attenuated the amount of parafoveal word information that was obtained for older adults.

**Regression Path Duration—**The fourth row of Table 2 shows the fixation time data for regression path duration for word N+1. There was a significant preview benefit of 62 ms in RPD, $\chi^2$ (1) = 21.90, $p < .001$. There was also a significant main effect of age, such that older adults' RPD was 51 ms longer than the younger adults, $\chi^2$ (1) = 4.43, $p = .04$. Additionally, the clause wrap-up contrast was marginally significant, $\chi^2$ (1) = 3.10, $p = .08$, and the sentence wrap-up contrast was significant, $\chi^2$ (1) = 11.00, $p < .001$. These effects were due to a shorter RPD for N+1 when word N was in the clause-final ($M = 401$ ms) or sentence-final position ($M = 369$ ms), compared to the sentence-internal position ($M = 433$ ms).

The middle panel of Figure 1 plots the preview benefit effect for RPD at all three word positions, for both younger and older readers. The Sentence Wrap-up X Preview X Age interaction was marginally significant, $\chi^2$ (1) = 3.32, $p = .07$. This was due to a significant Sentence Wrap-up X Preview interaction among older adults, $\chi^2$ (1) = 8.42, $p < .01$, but not among the young, $\chi^2$ (1) = 1.72, $p = .18$. The Clause Wrap-up X Preview X Age interaction was not significant, $\chi^2$ (1) = .49. Examining the effect of preview at conditional levels of sentence position revealed that the preview benefit was reliable across all word position conditions for younger adults. However, for older adults, word position moderated the

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[6] We also calculated two measures of refixation duration per Reingold et al. (2010): first fixation duration for trials with refixations ($FFD_{refix}$) and remainder gaze duration (rGD; the sum of first-pass fixation durations in trials with re-fixations, excluding the first fixation). These refixation duration measures were calculated only for trials where there was more than one first pass fixation. Because these refixations occurred on a small number of trials, there were significantly less data available for these analyses. Consequently, a large proportion of participants contributed no data to the refixation duration measures across at least one of the 6 within-subject conditions (e.g., in the sentence-internal, clause final, and sentence-final conditions, 53%, 55%, and 65% of participants did not refixate in either the valid preview or invalid preview conditions, respectively). Accordingly, only one significant effect was found across these two refixation measures (a significant preview benefit for $FFD_{refix}$, $p < .01$; no other effects of age, preview, word position, nor any interactions, reached significance, all $p$'s > .34), due in part to the reduced power and larger standard errors from the small sample size. However, the general pattern in the means for $FFD_{refix}$ and rGD were consistent with the findings from our later-pass measures, with older adults showing a smaller difference between the no preview and preview conditions in the sentence-final condition compared to the clause final and sentence-internal conditions, though these effects were not significant.

magnitude of the preview benefit, as there was a significant preview benefit of 92 ms in the sentence-internal condition, $\chi^2$ (1) = 14.06, $p < .001$, and a significant preview benefit of 50 ms in the clause-final condition, $\chi^2$ (1) = 4.35, $p = .03$, but there was no evidence of a significant preview benefit in the sentence-final condition among older adults, with a comparison of the invalid preview and valid preview conditions yielding a difference of 6 ms, which was not significantly different from zero, $\chi^2$ (1) = .03, $p > .50$. No other effects reached significance in RPD.

**Selective Regression Path Duration—**The fifth row of Table 2 shows the fixation time data for selective regression path duration for word N+1. There was a significant main effect of Preview, $\chi^2$ (1) = 17.21, $p < .001$, such that words with a valid preview ($M$ = 333 ms) had a significantly shorter sRPD than words without a valid preview ($M$ = 375 ms). Additionally, the main effect of age was significant, $\chi^2$ (1) = 4.20, $p = .04$, illustrating that older adults had a significantly longer sRPD (M= 354 ms) overall compared to younger adults ($M$ = 330 ms). The sentence wrap-up contrast was significant in sRPD, $\chi^2$(1) = 5.60, $p = .02$, such that N+1 had a shorter sRPD when word N was in a sentence-final position (M= 324 ms), compared to when word N was in a sentence-internal position (M= 358 ms).

Importantly, the Sentence Wrap-up X Preview X Age interaction was significant for sRPD, $\chi^2$ (1) = 5.42, $p = .02$. This effect is illustrated in the bottom panel of Figure 1. This was due to a significant Sentence Wrap-up X Preview interaction among the old, $\chi^2$ (1) = 15.60, $p < .001$, but not among younger adults, $\chi^2$ (1) = 1.02, $p = .31$. The Clause Wrap-up X Preview X Age interaction was not significant, $\chi^2$ (1) = 1.40, $p = .24$. Examining the effect of preview at conditional levels of sentence position revealed that the preview benefit was significant across all word position conditions for younger adults. However, for older adults, word position moderated the preview benefit, as there was a significant preview benefit of 78 ms in the sentence-internal condition, $\chi^2$ (1) = 19.53, $p < .001$, and a significant preview benefit of 50 ms in the clause-final condition, $\chi^2$ (1) = 9.89, $p < .01$, but no significant preview benefit in the sentence-final condition, with a comparison of the invalid preview and valid preview conditions yielding a difference of −3 ms, which was not significantly different from zero, $\chi^2$ (1) = .21. No other effects reached significance in sRPD.

**Proportion of regressions out—**The final row of Table 2 shows the proportion of regressions out of word N+1.The Preview effect was significant, $\chi^2$ (1) = 6.15, $p = .01$, indicating that the probability of launching a regression out of word N + 1 was greater if it was initially invalid (22%), compared to when it was a valid preview (14%). Additionally, the Sentence Wrap-up effect was significant, $\chi^2$ (1) = 3.70, $p =. 05$, indicating that the probability of launching a regression out of N+1 was greater when it was in a sentence-internal position (24%) compared to when it was the beginning of a new sentence (14%). No other effects significantly predicted the proportion of regressions out of word N+1 (all $p$'s $> .42$).

## Discussion

In the current study, a key assumption of the semantic integration hypothesis was tested, namely that wrap-up effects are resource-demanding, and as such, reduce the size of the preview benefit. Moreover, to the extent that the cognitive workload of wrap-up becomes more demanding with advancing age, we expected the preview benefit to be further attenuated among older adults as a function of wrap-up.

In the earliest measures of processing (FFD and SFD), wrap-up affected the preview benefit similarly for both younger and older adults, with both groups showing evidence for a reduction in the size of the preview benefit in the clause-final condition compared to the sentence-internal condition (and a trend in the reduction of the preview benefit in the sentence-final condition, though this effect was only marginally significant for SFD). However, for the intermediate and later pass measures, which include sources of variance from both first pass refixations (GD) and right-bounded re-reading time (RPD and sRPD), we found that age differences emerged. While younger adults showed no reliable effects of wrap-up on the preview benefit in these later measures, older adults showed a disproportionate disruption of the preview benefit as a function of sentence wrap-up, showing no evidence for a preview benefit in the sentence-final condition for gaze duration, regression path duration, or selective regression path duration (see Figure 1). The findings from the current study for the younger adults are consistent with findings from a recent study by White, Warren, and Reichle (2011) showing some evidence for effects of wrap-up on the preview benefit among younger adults for first-pass fixation measures, but not for later-pass fixation measures (Experiment 2). Under a semantic integration view, our findings suggest that sentence wrap-up was more costly for older adults, resulting in a greater cognitive workload and a concurrent reduction in the amount of parafoveal processing that could be accomplished. Thus, sentence wrap-up appeared to be more effortful for the older readers.

To the extent that first fixation duration and single fixation duration are more sensitive to more immediate and automatic cognitive operations, while gaze duration, regression path duration, and selective regression path duration may be more sensitive to slower cognitive operations (Clifton et al., 2007; Inhoff, 1984; Rayner, 1998; Rayner et al., 2010; Reingold, Yang, & Rayner, 2010), the findings from the current study suggest that the cognitive workload of sentence wrap-up continued to attenuate the preview benefit into later measures among the older adults only. The difference in the findings between early and late measures could be influenced by certain trials where wrap-up was more demanding, and thus where more time was needed to process the target word, rather than just emerging as an overall later cognitive process for the older adults. Rayner et al. (2010) found that when older adults allocated more time to refixating target words in certain trials during normal reading, likely due to processing difficulty in these cases, they showed a reduced preview benefit. However, in early pass measures (presumably in cases when processing load was not as high), they found that older adults did appear to show a parafoveal preview benefit on par with their younger counterparts. In this study, both younger and older adults showed similar effects of wrap-up on the preview benefit in early-pass measures (including trials where N+1 was only fixated ones). However, in trials where increased time was allocated to word N+1, (i.e., when N+1 was refixated and re-read, presumably due to extra processing difficulty), the pattern of results was markedly different, with older adults showing a disproportionate reduction in the preview benefit as a function of sentence wrap-up. It is worth noting that the current findings were not wholly consistent with the findings from Rayner et al. (2010) in that they found an attenuated preview benefit in sentence-internal positions among older adults in later pass measures, while we found no significant age differences in the preview benefit in the sentence-internal position for our later pass measures (GD, RPD, and sRPD). However, because the stimulus sentences differed across studies, this could be due to a number of other factors that might influence older adults’ preview benefit. Collectively, our findings suggest that, while the covert attentional mechanisms that underlie eye movement control during normal reading appear to remain intact with age, differences in the preview benefit may emerge specifically when the cognitive demands involved in sentence processing are high.

The findings from the current study do not necessarily conflict with the possibility that oculomotor or intonational mechanisms may play some role in determining fixation time at clause and sentence boundaries, as suggested by Hill and Murray (2000) and Hirotani et al. (2006). However, the collective results of the current study could not be explained under a strict dwell-time or oculomotor hypothesis, in which wrap-up effects are fully explained by these mechanisms. Under the dwell-time view, no differences would be expected in the preview benefit across clause or sentence boundaries. In fact, if the boundary site simply affords a place to pause while monitoring prosody, one might expect a larger preview benefit on word N+1, as readers would have more time to allocate covert attention to the word in parafoveal vision before fixating on it. Intonational boundaries (marked by punctuation), likely do play a role in wrap-up, but this does not preclude a mechanism whereby semantic and discourse updating work occurs at sentence and clause boundaries. For example, the findings from Stine-Morrow, Shake, et al. (2010) demonstrated that increasing boundary salience (by manipulating punctuation) increased the magnitude of wrap-up, which in turn, resulted in reduced processing costs downstream, consistent with the semantic integration hypothesis.

Few age differences were found in the effects of wrap-up at word N. Both younger and older adults showed increased fixation times on word N in the sentence-final and clause-final conditions, compared to the sentence-internal condition, but for single fixation duration, younger adults showed a larger wrap-up effect than older adults. This is in contrast to some studies (Miller & Stine-Morrow, 1998; Stine, 1990, Stine-Morrow et al., 2008) that have found more robust age differences in patterns of wrap-up. However, other studies have also shown age equivalence in wrap-up (Stine-Morrow et al., 2010), though typically at the cost of subsequent memory for text and comprehension for the older adults. According to a separate resource interpretation view of language processing (Caplan & Waters, 1999), there exists a separate and domain-specific system that supports online language processing. Importantly, according to this view, this language specific resource is not sensitive to conditions that deplete cognitive resources, such as aging. The finding that sentence-final processing reduced the preview benefit only among older readers is at odds with this model, which predicts no age-differences in online measures of language processing. It is important to note that the major age-differences found in the effects of wrap-up in this study emerged in the parafoveal processing of the word following the boundary. These findings illustrate the importance of using different metrics of processing difficulty to examine age-differences in online language processing.

Sentence and text comprehension involves the execution of immediate and incremental processes related to accessing lexical information, establishing sentence structure, and interpreting the semantic information in the text. That language processing is highly incremental does not preclude the existence of elaborative and integrative processes that can occur periodically during reading (Haberlandt & Graesser, 1989; Aaronson & Scarborough, 1976). Wrap-up effects appear to be one such mechanism, in which the semantic representation is consolidated and integrated with new information (Kintsch & van Dijk, 1978; Just & Carpenter, 1980; Rayner et al., 2000). Likely, there are dual processes ongoing in order to construct the mental representations underlying sentence and text comprehension, including linear and incremental processes (Pickering & van Gompel, 2006) and processes whereby segments of text that are in attentional focus and active in working memory (i.e., input cycles; Kintsch & van Dijk, 1978) are integrated with prior information. The findings from the current study suggest that this wrap-up effect is resource-demanding and that semantic integration at sentence boundaries may be less efficient with age, thus, resulting in a greater cognitive processing load.

## Acknowledgments

We wish to thank Kiel Christianson, Susan Garnsey, Keith Rayner, and two anonymous reviewers for their helpful discussions and comments on earlier drafts of this article. We are grateful for research support from the National Institute on Aging (R01 AG013935).

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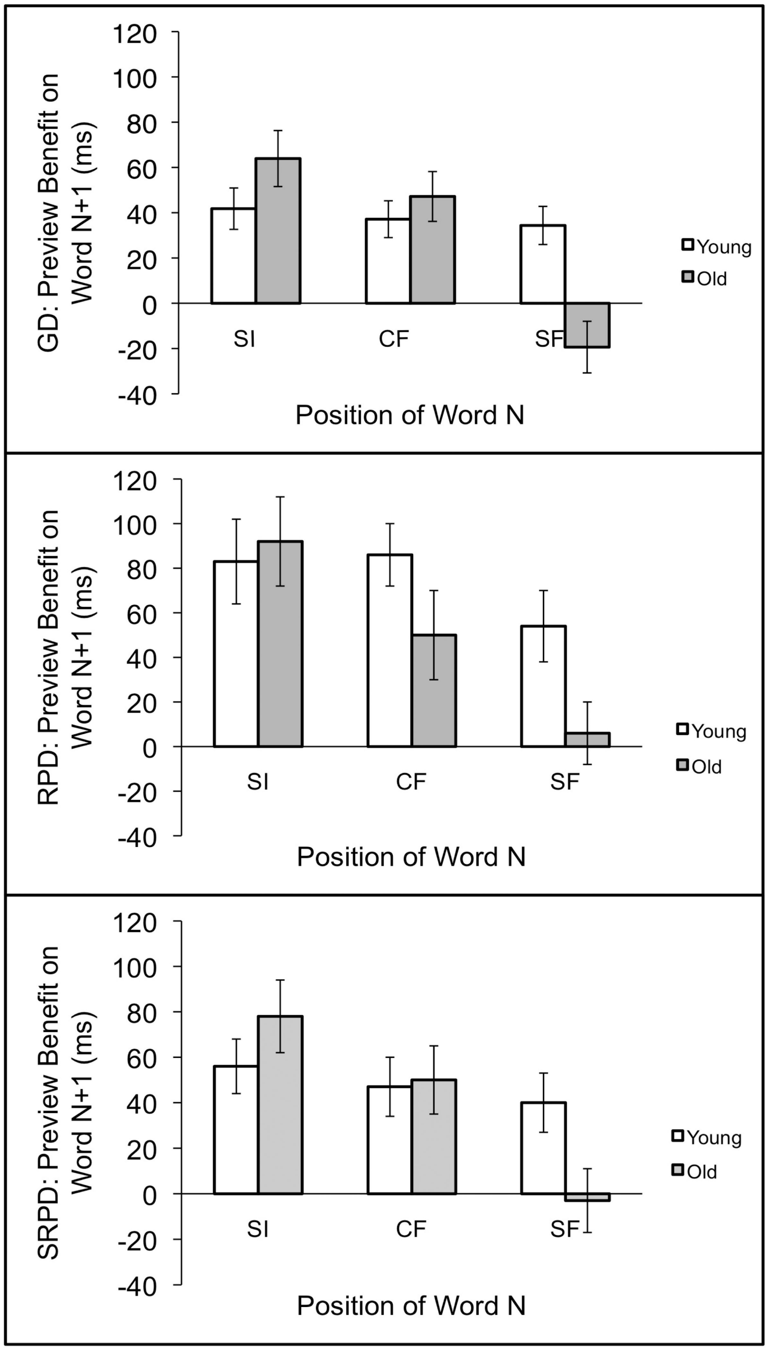

**Figure 1.**

Preview Benefit on Word N+1 as a Function of Age and Position of Word N for Gaze Duration (Top), Regression Path Duration (Middle), and Selective Regression Path Duration (Bottom).

*Note*. GD = Gaze Duration; RPD = Regression Path Duration; SRPD = Selective Regression Path Duration; SI = Sentence-Internal; CF = Clause-Final; SF = Sentence-Final; Preview benefit is difference between the preview and no preview conditions.

## Table 1

Average Temporal and Probability Measures for Word N as a Function of Word Position and Age.

| | | Measures | | | | | |
|---|---|---|---|---|---|---|---|
| **Word Position** | **Age Group** | **FFD** | **SFD** | **GD** | **RPD** | **sRPD** | **p(Regress)** |
| | Young | | | | | | |
| Internal | | 210 (8) | 213 (9) | 239 (13) | 295 (36) | 257 (19) | .14 (.02) |
| Clause-final | | 232 (8) | 229 (9) | 276 (13) | 383 (36) | 297 (19) | .17 (.02) |
| Sentence-final | | 236 (8) | 244 (9) | 287 (13) | 416 (36) | 319 (19) | .27 (.03) |
| | Old | | | | | | |
| Internal | | 232 (8) | 237 (9) | 273 (14) | 377 (39) | 299 (20) | .18 (.03) |
| Clause-final | | 237 (8) | 242 (9) | 283 (13) | 421 (38) | 312 (20) | .27 (.03) |
| Sentence-final | | 244 (8) | 249 (9) | 293 (14) | 470 (38) | 349 (20) | .29 (.03) |
| | Total | | | | | | |
| Internal | | 221 (6) | 224 (7) | 256 (10) | 336 (28) | 279 (15) | .16 (.02) |
| Clause-final | | 235 (6) | 235 (7) | 279 (10) | 402 (27) | 304 (15) | .21 (.02) |
| Sentence-final | | 240 (7) | 246 (7) | 290 (10) | 442 (27) | 334 (15) | .29 (.03) |

*Note.* FFD = First Fixation Duration; SFD = Single Fixation Duration; GD = Gaze Duration; (s)RPD = (Selective) Regression Path Duration; p(Regress) = Probability of First-Pass Regression Out; Standard errors are in parentheses.

## Table 2

Average Temporal and Probability Measures for Word N+1 as a Function of Word Position, Preview, and Age.

| Measures | Word Position | Younger Adults<br>Preview Condition<br>Invalid | <br><br>Valid | Older Adults<br>Preview Condition<br>Invalid | <br><br>Valid | Total<br>Preview Condition<br>Invalid | <br><br>Valid |
|---|---|---|---|---|---|---|---|
| FFD | Internal | 252 (9) | 222 (9) | 269 (10) | 219 (10) | 261 (7) | 220 (7) |
| | Clause-final | 230 (9) | 210 (9) | 248 (10) | 235 (10) | 239 (7) | 222 (7) |
| | Sentence-final | 237 (9) | 220 (9) | 263 (10) | 235 (10) | 250 (7) | 227 (7) |
| SFD | Internal | 263 (11) | 224 (11) | 272 (12) | 226 (11) | 268 (8) | 225 (8) |
| | Clause-final | 232 (11) | 218 (10) | 255 (12) | 241 (11) | 243 (8) | 229 (8) |
| | Sentence-final | 231 (11) | 221 (10) | 264 (11) | 242 (12) | 248 (8) | 231 (8) |
| GD | Internal | 307 (16) | 266 (16) | 321 (17) | 257 (17) | 315 (12) | 262 (12) |
| | Clause-final | 284 (16) | 247 (16) | 324 (17) | 277 (17) | 304 (12) | 262 (12) |
| | Sentence-final | 281 (17) | 247 (16) | 273 (17) | 292 (17) | 278 (12) | 270 (12) |
| RPD | Internal | 451 (17) | 368 (16) | 503 (19) | 411 (19) | 477 (13) | 389 (13) |
| | Clause-final | 415 (16) | 329 (17) | 454 (19) | 404 (19) | 435 (13) | 367 (13) |
| | Sentence-final | 389 (17) | 335 (17) | 376 (18) | 370 (19) | 383 (13) | 352 (13) |
| sRPD | Internal | 371 (14) | 315 (14) | 413 (15) | 335 (15) | 392 (11) | 325 (11) |
| | Clause-final | 351 (14) | 304 (14) | 385 (14) | 335 (15) | 369 (11) | 319 (11) |
| | Sentence-final | 339 (15) | 299 (14) | 327 (15) | 330 (15) | 333 (11) | 315 (11) |
| p(Refixate) | Internal | .25 (.04) | .17 (.03) | .25 (.04) | .21 (.04) | .25 (.03) | .19 (.03) |
| | Clause-final | .23 (.04) | .22 (.04) | .32 (.05) | .23 (.04) | .28 (.03) | .23 (.03) |
| | Sentence-final | .19 (.04) | .13 (.03) | .11 (.03) | .29 (.04) | .15 (.02) | .21 (.03) |
| p(Regress) | Internal | .27 (.04) | .16 (.03) | .30 (.05) | .21 (.04) | .29 (.03) | .18 (.03) |
| | Clause-final | .19 (.04) | .10 (.02) | .20 (.04) | .17 (.04) | .20 (.03) | .14 (.02) |
| | Sentence-final | .16 (.03) | .10 (.03) | .20 (.04) | .11 (.03) | .18 (.03) | .10 (.02) |

*Note.* FFD = First Fixation Duration; SFD = Single Fixation Duration; GD = Gaze Duration; (s)RPD = (Selective) Regression Path Duration; p(Refixate) = Probability of a First-Pass Refixation; p(Regress) = Probability of First-Pass Regression Out; Standard errors are in parentheses