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Younger and Older Adults' "Good-Enough" Interpretations of Garden-Path Sentences

Kiel Christianson
University of Illinois, Urbana-Champaign

Carrick C. Williams
Mississippi State University

Rose T. Zacks and **Fernanda Ferreira**
Michigan State University

Abstract

We report 3 experiments that examined younger and older adults' reliance on "good-enough" interpretations for garden-path sentences (e.g., "While Anna dressed the baby played in the crib") as indicated by their responding "Yes" to questions probing the initial, syntactically unlicensed interpretation (e.g., "Did Anna dress the baby?"). The manipulation of several factors expected to influence the probability of generating or maintaining the unlicensed interpretation resulted in 2 major age differences: Older adults were generally more likely to endorse the incorrect interpretation for sentences containing optionally transitive verbs (e.g., *hunted, paid*), and they showed decreased availability of the correct interpretation of subordinate clauses containing reflexive absolute transitive verbs (e.g., *dress, bathe*). These age differences may in part be linked to older adults' increased reliance on heuristic-like good-enough processing to compensate for age-related deficits in working memory capacity. The results support previous studies suggesting that syntactic reanalysis may not be an all-or-nothing process and might not be completed unless questions probing unresolved aspects of the sentence structure challenge the resultant interpretation.

In a recent series of articles, Christianson, Ferreira, and colleagues (Christianson, 2002; Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Ferreira, 2003; Ferreira, Bailey, & Ferraro, 2002; Ferreira, Christianson, & Hollingworth, 2001; Ferreira & Henderson, 1999) have presented evidence of shallow, or in their terms "good-enough" sentence processing. The overarching claim of this line of research is that on at least some occasions people may come away with interpretations of certain types of sentences that do not faithfully represent the true content of the sentences. In these articles, the authors point out that within the realm of cognitive psychology it is not controversial that mental representations of sensory information are often underspecified in some ways. For example, in the field of visual cognition, research has shown that viewers of a scene do not construct a veridical copy of that scene in their heads (Henderson & Hollingworth, 1999; Irwin, 1996; Simons & Levin, 1997). Likewise in the fields of judgment and decision-making (e.g., Kahneman, Slovic, & Tversky, 1982) heuristic-based decision-making allows for fast and frugal integration of input with less expenditure of both cognitive resources and time. The results in both cases are usually adequate, but they are occasionally wrong in predictable and testable ways.

Given that time, attention, and processing resources are limited in most real-world information processing tasks, including language, suspecting that the human sentence processor might be

Correspondence should be addressed to Kiel Christianson, Department of Educational Psychology, University of Illinois, Education Building, Room 226A, MC–708, 1310 S. 6th Street, Champaign, IL 61820. E-mail: kiel@uiuc.edu.

prone to less-than-complete processing as well on one or more levels of representation seems reasonable. In psycholinguistics, however, many believe that processing a sentence is generally completed fully and relatively automatically, and if this were not the case, the eventual interpretation derived from an underspecified linguistic representation would be suspect. MacDonald, Pearlmutter, and Seidenberg (1994), for instance, state that situations might arise in which "the communicative goals of the listener can be achieved with only a partial analysis of a sentence, but we view these as degenerate cases" (p. 686). The results Christianson et al. (2001) presented suggest that these "degenerate" cases are perhaps not so infrequent after all as we discuss in the following.

If demands and constraints on the human sentence parser indeed create conditions under which sentence processing operates in a good-enough or shallow mode, looking for further evidence of good-enough processing in people who are differentially affected by said demands and constraints would reasonable. One such group of people is the aged. Aging clearly affects cognitive function. Generally, although "mental mechanics" decline with age, knowledge continues to grow (Baltes, Staudinger, & Lindenberger, 1999; Stine-Morrow, Soederberg Miller, Gagne, & Hertzog, 2006). Specifically, speed of processing (Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1992), working memory capacity (Just & Carpenter, 1992; Kemper, 1986; Kemtes & Kemper, 1997), and inhibitory control (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999) are all adversely affected with age. This study sought to determine how the cognitive ramifications of aging affected the processing and subsequent interpretation of garden-path sentences. Our reasoning was simply that if we are right to believe that the human sentence processor operates at times in good-enough mode, then evidence thereof should be more apparent in older participants whose decreased cognitive efficiency should lead to less exhaustive processing. Before reporting the current experiments, we first summarize the method and results of Christianson et al. (2001), on which they were based, and then expand on two features of cognitive aging we hypothesized to have an observable impact on the misinterpretation of garden-path sentences: decline in inhibitory control and decreased working memory span.

CHRISTIANSON ET AL. (2001)

Contrary to the veridical view of sentence processing, Christianson et al. (2001) demonstrated consistent misanalyses of direct-object/subject garden-path sentences about which participants were nevertheless quite confident. They focused on the impact of the incorrect initial parse on the final interpretation of garden-path sentences. For example, for the sentence, "While Anna dressed the baby that was cute and cuddly played in the crib," they asked whether the initial interpretation that Anna was dressing the baby would affect the likelihood that people would eventually arrive at the ultimately correct interpretation that Anna was not in fact dressing the baby, but rather dressing herself while the baby played in the crib. Christianson et al. addressed this issue by having participants read garden-path sentences and then immediately answer questions that probed the specific thematic relationships established during the initial incorrect parse of the sentences' ambiguous regions (e.g., "Did Anna dress the baby?"). Across five experiments, their results indicated that people simultaneously maintain the temporarily ambiguous noun phrase (NP; *the baby*) as both the thematic patient of the subordinate clause verb (*dressed*) and as the thematic agent (and presumably the syntactic subject) of the matrix verb (*played*). Not only were participants highly likely to endorse this syntactically unlicensed interpretation of such garden-path sentences (evidenced by a high rate of "Yes" responses to the questions), they were also extremely confident in their responses, evidenced by a confidence rating collected after each response.

A likely contributor to the high rate of erroneous "Yes" responses was the occurrence of inferences based on knowledge about the world. For example, consider the sentence, "While

the man hunted the deer ran into the woods." The syntax of the fully reanalyzed sentence does not specify that the man was hunting the deer, but neither does it rule out this possibility. Given that the sentence contains a man, a deer, and hunting, and given what participants know about the activity of hunting, inferring that the man was hunting the deer even though the syntax does not specify this relation is plausible. In an experiment examining this possibility, Christianson et al. manipulated whether the conclusion of a sentence (e.g., "While the man hunted the deer that was brown and graceful …") made the garden-path interpretation more plausible (… *ran into the woods*) or less plausible (… *paced in the zoo*). Consistent with the idea that world knowledge affects the maintenance of the initial misinterpretation, participants were more likely to answer comprehension questions incorrectly following a plausible ending compared to a less plausible one.

However, evidence from other manipulations of garden-path stimuli in the Christianson et al. study indicates that inferences from general knowledge are not the only factor contributing to participants' tendency to endorse the original interpretation of garden-path sentence. In particular, Christianson et al. demonstrated that the misinterpretation effect is sensitive to conditions that affect parsing operations even when general knowledge inferences are unlikely to vary because the sentence content is held constant. For one thing, they showed that the misinterpretation effect was increased when the syntactically ambiguous region of the sentences was lengthened. For example, when participants read sentences such as, "While the man hunted the deer that was brown and graceful ran into the woods," and were then asked, "Did the man hunt the deer?" participants were more likely to respond "Yes" than when they were presented with shorter sentences such as, "While the man hunted the deer ran into the woods." This contrast demonstrated that the likelihood of misinterpreting such sentences was dependent on how long the incorrect garden-path structure had been maintained before syntactic disambiguation (the "head position effect"; Ferreira & Henderson, 1991). Christianson et al. also showed that the frequency of incorrect "Yes" responses to the comprehension questions was reduced when the syntactic garden path was eliminated either by reversing the order of the two clauses (e.g., "The deer that was brown and graceful ran into the woods while the man hunted") or by separating the clauses with a disambiguating comma (e.g., "While the man hunted, the deer …"). These findings suggest that reanalysis of garden-path questions is incomplete, but some reanalysis definitely occurs, which participants' responses to comprehension questions about the main clause (e.g., "Did the deer run into the woods?") demonstrated. Accuracy with main clause questions was close to perfect. This result confirmed that some reanalysis happened because some restructuring of the sentence was required to locate a subject for the main clause.

A final set of comparisons in the Christianson et al. study further examined the pervasiveness of partial reanalysis using a special, small class of verbs termed reflexive absolute transitive (RAT) verbs (Trask, 1993), for example, *wash*, *shave*, and *dress*. RAT verbs, unlike the optionally transitive (OPT) verbs such as *hunt*, *chew*, and *read*, retain transitive argument structures even when no syntactic object is overtly present. Specifically, the thematic patient of the RAT verb is understood as coreferential with the subject of the sentence (e.g., *Anna dressed* is synonymous with *Anna dressed herself*). If full syntactic reanalysis were actually being done on sentences such as, "While Anna dressed the baby played in the crib," and the misanalysis effects were due to inferential processes alone, sentences containing RAT verbs should block that inference. In other words, if Anna were dressing herself, then the interpretation that Anna was dressing the baby, derived from the initial parse of the garden-path sentence, is syntactically impossible. Full revision of RAT verbs should result in interpretations in which the agent and patient of the subordinate verb are coreferential, making it impossible that *the baby* is the patient of the verb *dressed*.

Christianson et al. found that even in the case of RAT verbs participants frequently misinterpreted the garden-path sentences. Moreover, whereas participants often endorsed the transitive interpretation of OPT verbs in non-garden-path sentences, with RAT verbs, "Yes" responses to transitive interpretations were rare. But in the garden-path conditions, the results for OPT and RAT verbs were much more similar (about a 60% rate of misinterpretations for RAT verbs vs. 70% for OPT). These findings imply that as long as participants were not garden pathed, they provided an implicit, reflexive object for the RAT verbs; but if they were garden pathed, the initial structure in which the ambiguous noun phrase (NP) was treated as object of the subordinate verb gave rise to a corresponding and tenacious transitive interpretation that blocked the syntactically licensed reflexive analysis. Christianson et al. attributed the entire pattern of results from their five experiments to good-enough processes in sentence processing, whereby the human sentence processor does enough syntactic reanalysis of an initial garden-path parse to obtain a plausible interpretation, but may terminate reanalysis before a fully licit syntactic representation is built (Christianson, 2002; Ferreira et al., 2001, 2002; Ferreira & Henderson, 1999).

AGE-RELATED EFFECTS ON SENTENCE PROCESSING

Age-related differences in working memory and inhibition are particularly relevant to the current study of how younger and older adults (mis)interpret garden-path sentences. The cognitive factor that has most often been studied in relation to age differences in language processing is working memory capacity. In the relevant research, working memory capacity is generally measured using some version of the Daneman and Carpenter (1980) reading span task in which participants read increasingly larger sets of sentences while trying to remember the final word of each sentence in the set. Older adults typically show deficits on these measures relative to younger adults (Waters & Caplan, 2003). Kemtes and Kemper (1997) found that older adults had greater difficulty answering comprehension questions about ambiguous (i.e., garden-path) sentences. They attributed this age difference, at least partially, to differences in working memory and pointed out that offline measures such as comprehension questions may be particularly revealing of working memory constraints. Interestingly, Kemper, Crow, and Kemtes (2004) found that when older adults with high working memory capacity read ambiguous sentences, they performed similarly to younger adults with equated working memory spans.

Although these findings seem to indicate that working memory capacity is an important factor in language comprehension, Caplan and Waters (1999; Waters & Caplan, 2002) have argued for an alternative view that isolates the syntactic parser from the cognitive resource measured by working memory capacity tasks. Among other results, Waters and Caplan (2001) found that older and younger adults showed similar effects of syntactic complexity in online processing measures despite the lower average working memory capacity of the older group. They take these results as evidence that working memory constraints do not affect syntactic processing. One potential resolution for these competing viewpoints comes from DeDe, Caplan, Kemtes, and Waters (2004), who used structural equation modeling to examine the connections of age, working memory, and both online measures of processing difficulty and off-line measures of comprehension. In their analyses, working memory was a mediator for the path between age group and comprehension measures but not online processing measures. They view these results as support for a separation of working memory from online language processing with working memory playing a role in the off-line comprehension.

Inhibition is another well-studied cognitive process that declines with age. Hasher, Zacks, and colleagues (Hasher & Zacks, 1988; Hasher et al., 1999) have proposed that older adults have greater difficulty than younger adults in inhibiting the activation of irrelevant information. Without efficient inhibitory mechanisms, older adults process more information that is not

directly related to the goal of the task than do younger adults, and performance on the task at hand suffers.

Inhibition has been shown to be an important component in the processing of discourse. Hamm and Hasher (1992) found that when reading a leading paragraph, older adults were more likely than younger adults to hold onto an original (but ultimately incorrect) interpretation of the paragraph. In a reading-aloud task, Connelly, Hasher, and Zacks (1991) found that older adults were more sensitive than younger adults to distracting text interspersed among the text they were reading and, furthermore, that this age difference was exaggerated when the distracting text was related to the topic of the text that had to be read aloud. Finally, Hartman and Hasher (1991; see also May, Hasher, Zacks, & Malthaup, 1999) found that when older and younger adults were required to provide a highly probable ending for a sentence and were then instructed to remember a less probable ending, older adults were more likely to remember the highly probable ending compared to younger adults. In other words, older adults were unable to inhibit the highly likely ending that they had generated even though they were instructed to remember a different one. All of these findings indicate that older adults process related but currently irrelevant information more extensively (more deeply and for longer durations) than do younger adults (Hasher et al., 1999).

The current study replicated and extended the work of Christianson et al. (2001) by examining age differences in the misinterpretation of garden-path sentences. Christianson et al. argued that thematic role assignments (i.e., agent, patient) made during the initial, incorrect parse of garden-path sentences linger. Moreover, they proposed that this residual thematic information might result in readers merging two conflicting partial parses into one interpretation that is inconsistent with the actual content of the sentence. If this is the case, older adults might be differentially hindered in their ability to answer similar comprehension questions. Older adults' reduced working memory capacity, decreased inhibitory processes, or both might result in even greater reliance on good-enough processing. To preview the results, younger and older adults were quite similar in their interpretations of garden-path sentences. Both age groups were relatively unsuccessful in obtaining licensed interpretations of such sentences. We interpret the differences that did arise between the age groups in the context of good-enough processing and age-related working memory deficits.

EXPERIMENTS 1A AND 1B

The current Experiments 1a and 1b manipulated two of the factors Christianson et al. (2001) found to affect sentence interpretation: structure of the sentences and verb type (see Table 1). The first factor investigated was sentence structure. All of the experimental sentences were presented with a main clause (e.g., *the deer ran into the woods*) and a subordinate clause (e.g., *while the man hunted*). Christianson et al. found that when the stimulus was a garden-path sentence (subordinate clause followed by the main clause: “While the man hunted the deer ran into the woods”), participants were more likely to endorse the garden-path interpretation (Q: “Did the man hunt the deer?” A: “Yes”), even though it is syntactically unspecified, than when the stimulus was not a garden-path sentence (main followed by subordinate: “The deer ran into the woods while the man hunted”). In this article we refer to the sentences that are presented with the subordinate clause followed by the main clause as the *garden-path order*, whereas sentences that are presented with the main clause followed by the subordinate clause will be referred to as the *non-garden-path order*.

In addition to sentence structure, verb type might affect the interpretation of garden-path sentences. Christianson et al. (2001) found that even RAT verbs were often misinterpreted when in garden-path sentences. As noted, reanalysis of a garden-path sentence containing an OPT verb in the subordinate clause (e.g., “While the man hunted the deer ran into the woods”)

should result in an intransitive interpretation of the verb in question, here *hunted.* To complete this reanalysis, verb argument structure must be changed from transitive to intransitive (Fodor & Inoue, 1998). With RAT verbs reanalysis should result in a transitive interpretation of the sentence whereby the object of the subordinate verb is coreferential with the subject of the subordinate clause (i.e., reflexive). RAT and OPT verbs could therefore lead to an age difference if reanalyzing sentences containing one type of verb is easier.

The current experiments investigated whether older adults would endorse comprehension questions probing initial incorrect interpretations of garden-path sentences more frequently than younger adults. The tendency of readers of any age to misinterpret a garden-path sentence might arise from the inability to inhibit the incorrect interpretation. More specifically, to the degree that inhibition of the initial, incorrect parse is necessary to derive the final, correct interpretation of a garden-path sentence (Vosse & Kempen, 2000), age-related inhibitory deficits (Hasher & Zacks, 1988; Hasher et al., 1999) should result in older adults experiencing greater difficulty than younger adults with unlicensed interpretations. non-garden-path structures should create fewer unlicensed interpretations for both age groups, but even for these sentences age differences could occur in processing. For example, if older adults derive more or more detailed inferences from what they read than younger adults, then we would still expect to find differences between the two groups in both garden-path and non-garden-path conditions for partially different reasons. Specifically, when sentences are not temporarily ambiguous, an age difference might be found due to differential reliance on inferencing; when sentences are ambiguous, differences might arise from both inferential and syntactic processes that vary with age. We did not expect the age groups to differ in their processing of the two verb types unless, as Christianson et al. speculated (and speculated earlier), RAT verbs proved easier to reanalyze than OPT verbs because their argument structure (which is always transitive) does not require reanalysis, as do the OPT verbs (Fodor & Inoue, 1998).

The difference between Experiments 1a and 1b was that sentence reading times were self-paced in Experiment 1a and experimenter paced in Experiment 1b. The latter procedure was introduced (and used in all subsequent experiments) to control for the prolonged reading times of the older adults in Experiment 1a, especially in the garden-path conditions. Although we report the methods of the two experiments together, we report the results separately.

Method

Participants—Twenty-four younger adults and 24 older adults were recruited to participate in both Experiments 1a and 1b. The younger adults received partial credit toward a requirement for general psychology courses at Michigan State University. Older adults were recruited from the community through advertisements in the local newspaper and retirement organizations. Older adults were paid $10 per hour for their participation. Table 2 details the mean education levels and vocabulary scores for these and all experiments. Older adults had significantly more years of education and better vocabulary scores than the younger adults.

Design and materials—The experiment had one between-groups factor (Age Group) and two within-groups factors (Verb Type and Sentence Structure). For the experimental items, sentences contained either OPT verbs (e.g., *hunted*)or RAT verbs (e.g., *dressed*). Twelve OPT verbs and 12 RAT verbs were selected (see Christianson et al., 2001 for a complete list of the materials) for the experiments. The Sentence Structure variable involves a comparison of garden-path and non-garden-path forms of the experimental sentences. Garden-path sentences consisted of a subordinate clause preceding a main clause (e.g., “While Anna dressed the baby that was small and cute played in the crib”), whereas the non-garden-path versions of the same sentences consisted of a main clause preceding a subordinate clause (e.g., “The baby that was small and cute played in the crib while Anna dressed”). The factorial combination of Verb

Types and Sentence Structures yielded six observations per cell per participant, and items were assigned to these conditions in a counterbalanced fashion across participants. In addition to the experimental items, 92 filler items from Christianson et al. were presented. The fillers had a structure of either subordinate–main clause or main–subordinate clause, but none were garden-path sentences. In total, the experiments had 116 items.

A comprehension question for each sentence (experimental and filler items) was created. The comprehension question for the experimental items asked about the critical thematic role assignment in each sentence (e.g., "Did Anna dress the baby?") regardless of sentence structure. The syntactically licensed answer to this question was "No." For the 92 filler items, half had a correct answer of "Yes," and half had a correct answer of "No."

Procedure—For all experiments presented here, stimuli were presented on a computer monitor and displayed using E-prime software (Beta 5 version) from Psychological Software Tools. The experiment was divided into five main components. At the beginning of the experiment, participants received general instructions, signed an informed consent form, and completed a general demographic questionnaire. After the participants completed these forms, they began the main portion of the experiment. The main task closely followed the procedure Christianson et al. (2001) used. In Experiment 1a, participants were presented a sentence in the center of a computer screen and were instructed to read the sentence at a normal rate and press a button when they had finished reading. The reading time for the sentence was measured from the sentence onset to the button press. In contrast, in Experiment 1b, the presentation time allowed for each sentence was yoked to the average reading time for that sentence for the younger adults in Experiment 1a. Because in Experiment 1a the older adults read more slowly overall than did the younger adults, in Experiment 1b a constant was added to the presentation time for a sentence for older adults based on the average age difference in the reading time for the filler sentences in Experiment 1a (1,643 ms).

In both experiments, after the sentence was removed and following a 500 ms interval, a yes-or-no comprehension question was presented in the center of the screen. Participants responded to the question and then rated their confidence in their response on a 4-point scale from 1 (*no confidence*) to 4 (*high confidence*). Consistent with Christianson et al. (2001), both age groups were highly confident in their responses overall with average ratings in Experiment 1a of 3.4 or higher. These high confidence ratings indicate that any misinterpretations we observe are not due to participants simply being confused about the sentences or giving up on processing them because they are challenging. The confidence data is therefore not discussed further in this study. The next trial began after a 1,000 ms response-to-stimulus interval.

Following the conclusion of the sentence judging trials, the participant was given a memory test for 32 of the filler items from the Sentence Judgment Task. The memory test was a two-alternative forced-choice test in which the participant had to choose the exact sentence that had been presented earlier. The foils included subtle changes to the meaning of the target sentence. For example, the presented sentence, "The bird flew over the house that was small and blue while it searched for a nesting place," had the foil, "The bird flew over the house that was small and white while it searched for a nesting place." The two alternatives were presented on the computer screen, one above the other. Participants indicated whether the top or bottom sentence was the exact sentence they had seen earlier. Half of the targets were presented in the top location and half were presented in the bottom location. Accuracy was the critical dependent measure. As Table 2 shows, younger adults remembered the sentences better than the older adults in each experiment reported here (although only numerically in Experiment 2). The memory test results indicate that although the older adults took longer to read the sentences in Experiment 1a, they were less able to remember the details of those sentences following the

task. We will discuss these memory results further in Experiment 3. We focus our discussion for now on the reading span task.

The fourth component of this experiment was a reading span task. The procedure used was similar to May, Hasher, and Kane (1999), in which participants read sets of sentences while simultaneously trying to remember the last word of each sentence. Sentences for this task were presented in the center of a computer screen. Participants were instructed to begin reading each sentence out loud at a normal rate as soon as it appeared on the computer screen and to press the space bar as soon as they had finished reading. Immediately following the button press, the next sentence appeared until the set was complete. When all of the sentences from a set had been presented, the recall display was shown. The participant was instructed to recall the final word from each of the sentences in the current set. The words could be recalled in any order with the limitation that the final word from the last sentence in a set could not be recalled first (to prevent recency effects from influencing the span measure). Five sets of sentences were given at each set size. We tested set sizes from two through four in ascending order. Although the range of set sizes was restricted to a maximum of four sentences, the reading span measure remained a difficult task with never more than one third of the participants being successful at the four-sentence span level (Experiment 1a, 1 older adult and 5 younger adults; Experiment 1b, 2 older adults and 6 younger adults; Experiment 2, 3 older adults and 3 younger adults; Experiment 3, 2 older adults and 10 younger adults).

Experiment 1a Results

Sentence judgment task—In all experiments reported here, we were interested in age differences in the likelihood of holding on to the original incorrect interpretation of garden-path sentences. To investigate this, we analyzed the proportion of trials on which the participant responded “Yes” to the question, “Did Anna dress the baby?” (i.e., the syntactically unlicensed answer, but the one consistent with a partial parse of the garden-path version of the sentence; see Table 1). Proportion “Yes” was used rather than an accuracy measure because we were interested in the likelihood of responding with an answer that was inconsistent with a fully licit reading of the sentences in the garden-path conditions.

As Figure 1 illustrates and as Christianson et al. (2001) found, both verb type and sentence structure had an effect on the proportion of incorrect “Yes” responses. Questions about sentences with OPT verbs were more frequently endorsed than questions about sentences with RAT verbs, $F1(1, 46) = 90.53$, $p < .001$, $MSE = 0.041$; $F2(1, 22) = 23.45$, $p < .001$, $MSE = 0.020$. Additionally, questions about garden-path sentences were answered “Yes” more frequently than questions about non-garden-path sentences, $F1(1, 46) = 46.38$, $p < .001$, $MSE = 0.112$; $F2(1, 22) = 91.32$, $p < .001$, $MSE = 0.030$. These effects were modulated by an interaction, $F1(1, 46) = 56.98$, $p < .001$, $MSE = 0.023$; $F2(1, 22) = 23.12$, $p < .001$, $MSE = 0.030$, in which sentences containing RAT verbs were more affected by the structure of the sentence than sentences containing OPT verbs. Specifically, questions about sentences with RAT verbs in a non-garden-path structure were highly unlikely to result in an endorsement of a garden-path interpretation. In contrast, even non-garden-path sentences with OPT verbs frequently yielded endorsement of the transitive interpretation. This difference reflects the baseline inference discussed earlier: Given the mention of a man, a running deer, and hunting, some participants will reasonably infer that the man was hunting the deer, even when the sentence appeared in non-garden-path sentences. Recall that RAT verbs must have a reflexive reading in non-garden-path sentences.

Overall, the older adults and younger adults responded similarly in this experiment, as Figure 1 clearly shows. By participants we found no main effect of age group in the proportion of “Yes” responses to the comprehension questions, $F1(1, 46) = 2.66$, $p > .10$, $MSE = 0.181$, but we found a difference when measured by items, $F2(1, 22) = 17.64$, $p < .001$, $MSE = 0.010$.

The difference between these two analyses most likely arose because the by-items comparison treats age as a within-items variable, whereas the by-participants analysis treats age as a between-participants variable. In neither analysis did an interaction occur between age group and sentence structure ($F1 < 1$; $F2 < 1$), indicating that older adults were not differentially affected by the garden-path sentences compared to the younger adults. Importantly, we found an age group interaction by verb type: Regardless of sentence structure, older adults endorsed questions about sentences containing OPT verbs more frequently than did younger adults, $F1(1, 46) = 5.62$, $p = .022$, $MSE = 0.041$; $F2(1, 22) = 13.77$, $p = .001$, $MSE = 0.010$. We found no age difference in the misinterpretation rates for questions about sentences containing RAT verbs, and we found no three-way interaction, $F1 < 1$; $F2(1, 22) = 2.33$, $p > .10$, $MSE = 0.004$.[1]

In summary, for responses to the comprehension questions, the lone age difference in this experiment was that older adults were more likely to endorse transitive interpretations of OPT verb sentences than were younger adults. No other factor affected the age groups differentially. Thus, the data failed to provide support for the hypothesis that inhibitory mechanisms play a role in the misinterpretation of garden-path sentences, which we discuss in the following section. The data do suggest that older participants relied on inference more heavily than younger participants.

Reading times—In addition to the comprehension question analysis, we also examined the time participants took to read the sentences. As Figure 2 shows, older adults took longer to read the sentences than younger adults, $F1(1, 46) = 10.62$, $p < .01$, $MSE = 36{,}289{,}184$; $F2(1, 22) = 84.47$, $p < .001$, $MSE = 2{,}281{,}891$. We found no effect of the verb type on the sentence reading time ($F1 < 1$; $F2 < 1$), but we did find significant effect of sentence structure with garden-path sentences being read for a longer time than non-garden-path sentences, $F1(1, 46) = 40.02$, $p < .001$, $MSE = 5{,}662{,}361$; $F2(1, 22) = 38.50$, $p < .001$, $MSE = 2{,}942{,}552$. The main effect of sentence structure was qualified by an interaction with age group, $F1(1, 46) = 5.64$, $p < .05$, $MSE = 5{,}662{,}361$; $F2(1, 22) = 6.56$, $p < .05$, $MSE = 2{,}431{,}907$, such that older adults showed longer reading times for garden-path sentences relative to younger adults. No other interaction was significant. The finding that older adults took significantly longer to read the garden-path versions of the sentences might explain their performance on the comprehension questions because the extra time the older adults spent reading could have compensated for the difficulty they were having parsing the garden-path sentences, in particular those with OPT verbs. Experiment 1b (and each of the subsequent experiments) addressed this concern by limiting the amount of time available for reading the sentences.

Experiment 1b Results

Sentence judgment task—The results for Experiment 1b mirror the results found for Experiment 1a (see Figure 3). Again, both verb type and sentence structure had an effect on the endorsement of transitive interpretations. Questions about sentences containing OPT verbs

[1]The data described clearly demonstrate that older and younger adults respond similarly to the questions probing the initial misunderstanding of the garden-path sentence. However, for this to be of significance, we must also demonstrate that older adults are similar to younger adults in obtaining a licensed interpretation of the main clause of the sentence. Christianson, et al. (2001) demonstrated that younger adults successfully acquire the licensed reading of the main clauses of OPT sentences (e.g., after reading *While the man hunted the deer ran into the woods*, participants correctly respond yes to the question, *Did the deer run into the woods?*). Twelve younger and 12 older adults were tested on their interpretations of the main clause of OPT verb sentences by asking comprehension questions that focused on that portion of these sentences. Forty-eight OPT verb sentences from Experiment 2 were presented in the garden-path clause order or in the non-garden-path clause order. Both age groups were able to obtain a correct interpretation of the main clause (younger adults: garden path = .91, non-garden path = .92; older adults, garden path = .88, non-garden path = .91) and there were no age differences or interactions (all Fs < 1). These findings indicate that both age groups perform enough reanalysis to derive the correct interpretation of the main clause in this type of garden-path sentence. The questions here concern the main clause of the sentences rather than the subordinate clause that contained the RAT or OPT verb. Thus, there is little reason to anticipate that the results would be different had we tested the RAT verb sentences in this manner.

were more frequently answered incorrectly ("Yes") than were questions about sentences containing RAT verbs, $F1(1, 46) = 138.07$, $p < .001$, $MSE = 0.034$; $F2(1, 22) = 33.01$, $p < .001$, $MSE = 0.068$, and questions about garden-path sentences were answered "Yes" more frequently than were questions about non-garden-path sentences, $F1(1, 46) = 74.56$, $p < .001$, $MSE = 0.070$; $F2(1, 22) = 107.43$, $p < .001$, $MSE = 0.025$. As in Experiment 1a, these effects were qualified by an interaction, $F1(1, 46) = 91.16$, $p < .001$, $MSE = 0.021$; $F2(1, 22) = 35.43$, $p < .001$, $MSE = 0.025$, that indicated that sentences with RAT verbs were more affected by the sentence structure than sentences with OPT verbs.

The similarity in performance for the two age groups from Experiment 1a was replicated in this experiment. We found no main effect of age group in the proportion of garden-path responses in the participants analysis ($F1 < 1$), but we did find a marginal difference in the item analysis, $F2(1, 22) = 4.12$, $p = .055$, $MSE = 0.011$. Again, age group did not interact with the sentence structure ($F1 < 1$; $F2 < 1$). However, as in Experiment 1a, an age group interaction was found with verb type in that older adults, regardless of sentence structure, more frequently responded "Yes" to questions about sentences containing OPT verbs (but not RAT verbs) than did younger adults, $F1(1, 46) = 4.86$, $p = .033$, $MSE = 0.034$; $F2(1, 22) = 4.96$, $p = .037$, $MSE = 0.011$. No three-way was found interaction ($F1 < 1$; $F2 < 1$).

Reading span results—Performance on the reading span test administered to all participants (see Table 2) was scored by counting the total number of words recalled correctly throughout the span task (see May et al., 1999). In both Experiments 1a and 1b, younger adults outperformed older adults. The age difference was only marginal in Experiment 1a, $t(46) = 1.98$, $p = .054$, but it was significant in Experiment 1b, $t(46) = 2.62$, $p < .05$. These results replicate several findings of age differences on memory span tasks that use increasing set size during testing (e.g., Lustig, May, & Hasher, 2001;May et al., 1999;Waters & Caplan, 2001).

To investigate the possibility that reading span is related to comprehension, we correlated the performance on the span measure with the proportion of "Yes" responses to the experimental sentences. Because we found no differences in the results of Experiments 1a and 1b, we collapsed across the two experiments. As Table 3 shows, older adults demonstrated an overall pattern of negative correlations between reading span and comprehension errors. These correlations were significant for the garden-path conditions. These results contrast with those for young adults who produced only one marginally significant trend among the four correlations. The correlational data suggest that older adults with larger reading spans were capable of answering the comprehension questions more accurately (were less likely to answer "Yes"), especially when confronted with a garden-path sentence. However, the relation between memory and comprehension was not evident for younger adults. The older adults in these experiments had smaller overall reading spans than their younger counterparts. Together these findings suggest that working memory plays a significant role in answering comprehension questions such as those used here. We will return to a discussion of the role of working memory in the answering of comprehension questions in Experiment 3.

Discussion

Experiments 1a and 1b demonstrated that participants were willing to endorse the initial, incorrect interpretations of garden-path sentences after they had finished reading them, replicating Christianson et al.'s (2001) findings. The data suggest that the thematic roles assigned during the initial, incorrect parse of garden-path sentences influenced the ultimate interpretations people derived from such sentences. Older adults and younger adults were very similar in their responses to the comprehension questions in these experiments. Both age groups were more likely to endorse unlicensed interpretations following garden-path sentences compared to non-garden-path sentences, indicating that the two age groups engaged in about

the same amount of reanalysis. The similarity in performance cannot be attributed to excessively longer reading times for the older participants because in Experiment 1b presentation time was functionally equated; however, the relation between reading span and comprehension, specifically for older adults, appears to support a role for working memory in answering the comprehension questions.

The major age difference in Experiments 1a and 1b was that older adults were more likely than younger adults to be left with transitive interpretations of sentences containing OPT verbs, in both garden-path and non-garden-path sentences. This age difference was not observed in sentences containing RAT verbs. We would not have expected the observed difference between verb types if inhibition were implicated in the performance of the two groups; given that garden-path sentences result in initial, incorrect parses irrespective of verb type, no difference should be associated with the amount of inhibition required to inhibit that initial parse. However, perhaps inhibition of alternative syntactic parses is not relevant to the sort of good-enough processing proposed here. If people construct only one incomplete structure, or two partial, incompatible syntactic structures (tree-splicing in the terminology of Christianson et al., 2001), then no competition between structures would exist. Another possibility is that conflicting representations exist at separate levels of analysis—say, the syntactic and semantic levels—that, although conflicting, are not checked against one another or integrated absent a strong error signal (a possibility Christianson et al. also discussed). We explore these issues further in the subsequent experiments, as well as in the general discussion.

EXPERIMENT 2

One reason why older and younger participants might have differed in their interpretation of both garden-path and non-garden-path sentences containing OPT verbs is that the syntax of OPT verbs allows for more inference. If one is hunting in general (intransitive *hunt*), one might also be hunting a deer, but if one is dressing, one must be dressing a *specified* object, possibly oneself. This fact arises from the obligatorily transitive argument structure of RAT verbs. Thus, one could reason that the older and younger adults' different responses to OPT verb sentences arose due to older adults' overreliance on inference generation (Hartman & Hasher, 1991). To investigate this idea, in Experiment 2 we changed the stimuli so that for sentences with OPT verbs the natural inference that “the man was hunting the deer” would be far less plausible (see Table 4). For example, in the sentence, *While the man hunted the deer ran into the woods*, the man could plausibly be hunting the deer mentioned in the sentence. However, in the sentence, “While the man hunted the deer paced in the zoo,” the same semantic representation is implausible because hunting of zoo animals is generally not permitted. Christianson et al. (2001) found that the implausibility of the proposition that the man was hunting a deer in a zoo was sufficient to trigger reanalysis beyond the good-enough process usually found with plausible garden paths.

If older adults are more willing to make plausible inferences than are younger adults, then they would be more willing to endorse a plausible but unlicensed interpretation. In the absence of a clear implausibility, older participants may be more likely to rely on a good-enough analysis of the sentence to avoid having to reinstantiate the verbatim content of the sentence for reanalysis, thus easing working memory burden. If this idea is right, it would be consistent with findings indicating that older adults perform as well as younger adults on memory tests that allow for plausible inferences to assist in memory (Reder, Wible, & Martin, 1986). We expected that the age difference would remain when the misinterpretation was plausible, but disappear when the misinterpretation was implausible.

In addition to plausibility, we also manipulated the length of the potentially ambiguous NP. The ambiguous region for garden-path sentences is the region after the subordinate verb

beginning with the determiner *the* and ending with the disambiguating verb (e.g., "While the man hunted the deer **ran**"; the ambiguous NP is underlined and the disambiguating word is in boldface). Ferreira and Henderson (1991) found that when the ambiguous NP was short (e.g., … *the deer* …), participants were less likely to find the sentence ungrammatical compared to when the ambiguous region was long (e.g., … *the deer that was brown and graceful* …). Christianson et al. (2001) found an analogous effect when participants were asked comprehension questions: Long ambiguous regions led to significantly more misinterpretations than did short ambiguous regions. All the sentences used in Experiments 1a and 1b had relatively long ambiguous regions.

The length of the ambiguous region could influence the likelihood that older adults respond with a garden-path interpretation. For all participants, the amount of time that they are committed to a garden-path structure affects the likelihood that they endorse the corresponding (mis)interpretation. However, once committed to an interpretation for a longer period of time, older adults may have more difficulty than younger adults inhibiting the initial interpretation and revising accordingly (if, as discussed previously, two parses are actually in competition). This would be similar to the findings of Hamm and Hasher (1992), who found that older adults held on to an original interpretation of a paragraph even after this interpretation became untenable. Thus, we might find an age difference when the ambiguous NP is long.

Method

Participants—Twenty-four younger adults and 24 older adults participated in this experiment. Participants were recruited from the same sources as those in Experiment 1a and 1b. Table 2 details the demographic information. None had participated in Experiment 1.

Materials and procedure—The materials for this experiment were similar to those Christianson et al. (2001) used in Experiment 1. Forty-eight sentences with OPT verbs were used; no RAT verb sentences were included. Eight within-subject experimental conditions were based on the factorial combination of the three within-participant factors in this experiment: sentence structure (garden path or non-garden path), plausibility of the misinterpretation (plausible or implausible), and length of ambiguous region (long or short). As the examples in Table 4 show, plausibility was manipulated by changing the end of the main clause so that the ambiguous NP (e.g., *the deer*) was unlikely to be the object of the OPT verb in the subordinate clause (e.g., *hunted*). In the example sentence, that anyone would hunt a deer in a zoo is unlikely. Each OPT verb was presented in a sentence in each of the eight conditions, which was counterbalanced across participants. The same filler sentences were used as in the previous experiments with the addition of 24 filler items that had neither main–subordinate nor subordinate–main structures. Sentences were presented for a specific amount of time based on a regression of the reading time for the filler sentences from Experiment 1a. For young adults, each sentence was presented for 326 ms plus 401 ms per word in the sentence. As in Experiment 1b, an additional 1,643 ms per sentence was added for older participants. All other aspects of the procedure were the same as in the previous experiments.

Results

Sentence judgment task—As Figure 4 shows, sentence structure, plausibility, and length of ambiguous region each had the expected effects on the likelihood of endorsement of a garden-path interpretation. Questions following garden-path sentences were responded to incorrectly ("Yes") more frequently than were questions for non-garden-path sentences, $F1(1, 46) = 16.78$, $p < .001$, $MSE = 0.061$; $F2(1, 47) = 21.89$, $p < .001$, $MSE = 0.096$. Plausible continuations led to more endorsements than implausible continuations, $F1(1, 46) = 115.01$, $p < .001$, $MSE = 0.059$; $F2(1, 47) = 84.79$, $p < .001$, $MSE = 0.161$. And transitive interpretations were endorsed more frequently in sentences with long ambiguous regions compared to short

ambiguous regions, $F1(1, 46) = 37.89$, $p < .001$, $MSE = 0.042$; $F2(1, 47) = 47.15$, $p < .001$, $MSE = 0.068$. These results replicate those Christianson et al. (2001) found. In addition, we found a significant two-way interaction between the length of the ambiguous region and the sentence structure, $F1(1, 46) = 25.84$, $p < .001$, $MSE = 0.036$; $F2(1, 47) = 35.11$, $p < .001$, $MSE = 0.054$. This interaction resulted from the fact that the garden-path structures had little effect on responses in the short condition, but in the long condition, the effect of structure was large. We also found a marginal interaction between the structure of the sentence and the plausibility of the inference, $F1(1, 46) = 2.85$, $p = .098$, $MSE = 0.033$; $F2(1, 47) = 3.43$, $p = .07$, $MSE = 0.055$, such that structure had a greater effect on the endorsement rates for the implausible sentences than for the plausible sentences. These results are expected given the findings Christianson et al. (2001) reported.

The main points of interest for the current experiment are the age group comparisons. As in Experiments 1a and 1b, older adults demonstrated higher endorsement rates of garden-path interpretations than did younger adults, $F1(1, 46) = 8.76$, $p < .01$, $MSE = 0.21$; $F2(1, 47) = 44.29$, $p < .001$, $MSE = 0.082$. Also as in Experiments 1a and 1b, sentence structure did not interact with age group, $F1 < 1$; $F2(1, 47) = 1.94$, $p > .10$, $MSE = 0.060$. More critical for the current experiment, however, were the possible interactions of age group with plausibility and with length of the ambiguous NP. However, these interactions were not observed: Age did not modulate the effect of plausibility ($F1 < 1$; $F2 < 1$) nor did it influence the effect of ambiguous NP length ($F1 < 1$; $F2 < 1$). These results indicate that older and younger adults were affected similarly by all manipulations, including plausibility. No higher order interactions with age group were significant ($F1$s < 1.5; $F2$s < 2).

Reading span results—Although the reading span results were in the expected direction in Experiment 2, the difference favoring the younger group was small and not significant, $t(46) = .977$, $p = .334$. We nonetheless proceeded to examine the correlations between reading span and comprehension test performance. Although the pattern of correlations does not completely replicate that obtained in Experiments 1a and 1b, Table 5 offers more evidence for a relation between span and comprehension among older adults than younger adults, particularly in the garden-path conditions (3 of 4 significant or marginally significant correlations for older adults, none for younger adults). Somewhat surprisingly, the older adults showed significant negative correlations between reading and comprehension errors in the implausible garden-path condition. This result seems to indicate that older adults with smaller reading spans tended to ignore the obvious implausibility of the sentence and endorse the unlikely garden-path interpretation.

Discussion

The results of Experiment 2 replicate with a larger set of OPT verbs the finding that older adults more frequently endorse transitive interpretations of OPT verb sentences than do younger adults. Importantly, although the plausibility manipulation had the expected effect overall on the comprehension performance of both age groups, we found no evidence that the plausibility of the continuation of a sentence (and thus the transitive misinterpretation) or the length of the ambiguous NP modulated the age difference in the endorsement rate. Thus, the age effects observed in Experiments 1a and 1b probably cannot be attributed to older people relying more heavily on plausibility to guide their inferences about the notional objects of intransitive OPT verbs. The low-span participants were in fact more likely to respond “Yes” incorrectly in both the plausible and implausible conditions. Finally, the length of the ambiguous region did not interact with age either, and thus it appears again that the likelihood of misinterpreting a garden-path sentence does not depend on the success of inhibiting the incorrect interpretation.

EXPERIMENT 3

Experiments 1a and 1b demonstrated that when older participants encounter OPT verbs such as *hunt* in the intransitive form, they are more likely than younger adults to draw a pragmatic inference linking the potential object slot with a plausible entity somewhere in the sentence. The second experiment ruled out the possibilities that this age difference was due to plausibility of the transitive interpretation or the amount of time older versus younger adults were committed to the incorrect garden-path structure. Because we found no age effects for the RAT verbs that we studied in the first experiment, we decided to focus more closely on the differences between the argument structures of the two verb types that might have led to the age effects. Recall that a critical difference between the two verb classes is that RAT verbs have a specified, transitive interpretation even when they occur with no overt object (i.e., with a null anaphor in object position). Transitive structures of OPT verbs, on the other hand, contain a specified object (e.g., the man was hunting *the deer*), whereas intransitive structures require that the OPT verb have an unspecified interpretation (e.g., the man was hunting in general, with no specified quarry). This distinction could lead to the age difference that we observed in the previous experiments.

In answering comprehension questions such as, “Did the man hunt the deer?” participants can either reactivate the verbatim content of the relevant sentence (along with the associated syntactic representation), or they can rely on their memory for the propositional content of the sentence. Syntactic structure decays rapidly in memory (Sachs, 1967), and so expecting participants with smaller memory spans (generally the older participants in these experiments) to rely on propositional content to answer the questions is reasonable. In the case of the OPT verb sentences, two propositions (represented in capital letters) exist. One, derived from the initial syntactic misanalysis from a general inference process, or both is specified: THE MAN HUNTED THE DEER. The second, derived from a full syntactic reanalysis, is unspecified: THE MAN HUNTED [SOMETHING]. Note that the first proposition entails the second: if one is hunting a deer, one is necessarily hunting something.

Consider now the RAT verbs, as in the sentence, “While Anna dressed the baby played in the crib.” The first proposition, derived from an initial syntactic misanalysis, is ANNA DRESSED THE BABY. The second, derived from reanalysis, is ANNA DRESSED [HERSELF]. Note that in this case the first proposition does not entail the second. Crucially, neither clause generates a proposition in which ANNA DRESSED [SOMETHING] with that “something” remaining unspecified. The semantics of RAT verbs force a specified interpretation.

Due to memory span limitations, older adults—even those who fully reanalyze garden-path sentences—are possibly more likely than younger adults to rely on their memory for propositional content rather than on their ability to recall the sentences verbatim (see Tun, Wingfield, Rosen, & Blanchard, 1998, for a similar argument that older adults rely on gist memory more than younger adults in a false memory task). Older adults, then, would be expected to answer “Yes” to “Did the man hunt the deer?” more often than younger adults because they are more likely to rely on the propositionally based representation. In the case of the OPT verb sentences tested in Experiments 1 and 2, the two propositions—that THE MAN HUNTED THE DEER and that THE MAN HUNTED [SOMETHING]—are congruent, and thus we find little reason to answer “No.” Younger adults presumably also rely on propositional content in answering comprehension questions some proportion of the time, but they are more likely to be successful in reinstantiating the structure of the garden-path sentence at the prompting of the question (due to their larger memory spans).

Notice that global, real-world plausibility is not the issue, as we demonstrated in Experiment 2. It is rather a matter of incongruent propositional content triggering the need to reinstantiate

the sentence structure of the garden-path sentence. In the RAT verb sentences, the incongruency between initial and revised propositions does not allow for as many "Yes" answers for either age group. Participants "know" that Anna dressed something specific (according to the semantics of the verb), but that this specific something cannot be the baby (according to the syntax of the sentence).[2] For the OPT verb sentences, congruency allows older adults—even those who may have reanalyzed the sentences completely—simply to check what is most easily accessible: a "gist"-like memory for the propositions, rather than "verbatim"-like memory for the structure.

What evidence do we have that older adults rely on their memory for propositional content rather than the syntactic structure of the sentence to answer our comprehension questions? First, we have found relations between a measure of working memory (reading span) and the likelihood of answering a comprehension question incorrectly. Thus a connection seems to exist between the memory and the ability of participants to reinstaniate the original context of the sentence for answering a question. Another piece of evidence could be obtained by asking a question that would force the reinstantiation of the syntactic structure. Precisely such a question would be, for example, "Did Anna dress herself?" Chomsky's (1986) binding theory posits that the coreferential co-indexation of reflexive pronouns and their antecedents requires that a circumscribed syntactic relation (called constituent-command or c-command) exist between the two elements. This relation is by theory defined in purely structural terms; it cannot be derived from semantic or propositional content. If, as Christianson et al. (2001) proposed, syntactic reanalysis can terminate before it is carried out completely, the co-indexation of the null anaphor and its antecedent might not be performed by participants who do not fully reanalyze garden-path sentences. In other words, participants who answered "No" to "Did Anna dress the baby?" may have done so because they had fully reanalyzed the sentence. Additionally, they may have answered "No" because *dress* must have a specific interpretation whether an overt object is present. Anna could not have been dressing the baby *and* dressing some unspecified thing, so, because *dressed* requires a subject/agent and *the baby* is the only NP available, the answer should be "No." If this line of reasoning is correct, we would expect older adults to answer the question "Did Anna dress herself?" less accurately than younger adults. The motivation for this prediction is that to answer this question correctly ("Yes"), those participants who did not reanalyze fully during the first reading of the sentence need to reinstantiate the syntactic structure of the sentence so that the subject and null anaphor occur in a c-command relation to one another such that coreferential co-indexation can take place. We are therefore forced to make an unexpected prediction: If the difference between older and younger adults that we have observed in sentences containing OPT verbs can be explained in the way described earlier, then we should also find a difference in the two groups' interpretation of sentences with RAT verbs, a difference we have failed to observe so far because we have not asked the right comprehension question.

Up to this point, we have asked comprehension questions that focused on the unlicensed interpretations of the sentences. Experiment 3 examined whether age differences exist in attaining the licensed interpretation of the subordinate clause. The most direct way to examine this issue is to ask a comprehension question such as, "Did Anna dress herself?" If, as we argued earlier, answering this question sometimes requires the reinstantiation of the syntactic structure of the garden-path sentence, older adults whose memory spans are typically smaller than younger adults should be less likely to answer this question correctly. (Note that a correct response is to say "Yes," in contrast to all the previous experiments.)

[2]Recall that in footnote 1, there was no significant difference in the rate with which older and younger adults correctly answered questions about the main clause.

Only subordinate clauses of RAT verb sentences were tested in Experiment 3 because RAT verbs allow for the direct interpretation question, “Did Anna dress herself?” To probe the parallel interpretation in OPT verb sentences, we would have had to ask awkward questions such as, “Did the man hunt some unspecified quarry?” which would obviously be impractical.

Method

We tested participants' reflexive interpretations of the subordinate clause of the RAT verb sentences used in Experiment 1b. A subset of the individuals who participated in Experiment 2 and another experiment—a total of 57 younger and 59 older adults—participated in Experiment 3 after completing the other experiment. Not all of the individuals who participated in the previous experiments were included in this additional testing session due to time constraints. Following the main experiment, these individuals were presented with another list of items that included both OPT and RAT verb sentences. The OPT verb sentences and comprehension questions were the same as those used in Experiments 1a and 1b and had been seen previously in some form in the main experiment. These items served as fillers in the additional test and the participants' responses were not analyzed. The critical items for this part of the study were the sentences containing the RAT verbs. These sentences and the presentation procedure were the same as in Experiment 1b, except that instead of asking about the syntactically unlicensed interpretation of a sentence, the comprehension questions probed the licensed (i.e., reflexive) interpretation (e.g., “Did Anna dressed herself?”). Because Experiment 2 did not use RAT verbs, none of the participants in Experiment 3 had previously seen any version of these stimuli. Unlike in the previous experiments, the critical data for Experiment 3 were the accurate, rather than the inaccurate, responses to the comprehension questions regarding the subordinate clause.

Results

Subordinate clause interpretation—To examine the correct interpretation of the subordinate clause, we examined the accurate “Yes” responses for both younger adults and older adults within each sentence structure for the RAT verb sentences only. As Figure 5 shows, there was an effect of sentence structure, $F1(1, 114) = 53.95$, $p < .001$, $MSE = 0.046$; $F2(1, 11) = 38.96$, $p < .001$, $MSE = 0.014$, an age difference, $F1(1, 114) = 6.85$, $p = .01$, $MSE = 0.095$; $F2(1, 11) = 15.43$, $p = .002$, $MSE = 0.009$, and an age interaction with sentence structure, $F1(1, 114) = 14.88$, $p < .001$, $MSE = 0.046$; $F2(1, 11) = 31.04$, $p < .001$, $MSE = 0.005$. Both age groups showed significant drops in accuracy for the garden-path structures compared to the non-garden-path structures: younger adults, $t(56) = 2.74$, $p = .008$; older adults, $t(58) = 7.30$, $p < .001$. The most notable aspect of Figure 4 is the interaction between age group and sentence structure. When a non-garden-path sentence was presented, the two age groups responded equally accurately, $t(114) = 0.089$, $p > .2$, to the question regarding the reflexive interpretation of the subordinate verbs. However, when the sentence was presented in the garden-path structure, older adults were significantly less likely to answer the reflexive question correctly than were younger adults, $t(114) = 3.45$, $p < .01$. Finally, for the garden-path conditions, we tested each age group's comprehension question accuracy against a chance level of 50%. Younger adults performed significantly better than chance, $t(56) = 5.66$, $p < .001$, in responding to the correct interpretation of the subordinate clause. In sharp contrast, the older adults' accuracy was no better than chance, $t(58) = .312$, $p > .2$.

The response patterns to the reflexive questions confirm our unexpected prediction, and thus provide strong evidence that younger adults are better capable of reinstantiating such sentences verbatim (along with the syntactic structure) and working out the c-command relation required to establish the coreferential relation between null reflexive pronoun and antecedent, whereas older adults are more likely to rely solely on the propositional content of the sentence. The semantics of the RAT verbs ensure that the propositional content does not allow for Anna to

be dressing both the baby and some unspecified dressee. Crucially, however, the propositional content does not force a reflexive interpretation, either; only the syntax can do that.

These results are fully consistent with the idea that participants do not necessarily fully resolve the syntactic ambiguities of garden-path sentences at the time of reading. Instead, they resolve enough of the structure to obtain a semantic interpretation of the main clause that is good enough (Ferreira et al., 2001, 2002) under most conditions, and they leave the remainder of the sentence unrepaired. In the case of our RAT verb sentences, readers repair the main clause so that the baby is represented as the agent of playing in the crib (see footnote 1). However, readers do not necessarily realize that the subordinate clause structure originally built is now without an object and therefore unlicensed. The presence of the comprehension question appears to require them to examine the syntactic structure of the subordinate clause. They then determine that the structure originally built is now untenable. Once this realization takes place, if the original sentence can be accessed in memory, the lexicon can be consulted to determine what if any alternative argument structures the verb might have (Fodor & Inoue, 1998). In the case of RAT verbs, they would check the lexicon to make sure it allows a reflexive null object.

According to this view, a complete reanalysis of the subordinate clause primarily takes place after the processing of the probe question and requires the reinstantiation of the original sentence syntax. Answering accurately, therefore, places a heavy demand on working memory. Given that older adults tend to have smaller reading spans (as demonstrated in Experiments 1 and 2), they should be less able to answer these questions accurately.

To explore this potential link between working memory and the results of Experiment 3, we correlated the reading spans of the participants with their accuracy in answering the reflexive question (see Table 6). The memory load explanation should be limited to the garden-path condition because the subordinate clause in the non-garden-path condition is the portion of the sentence that is closest to the question and thus recency should come into play. For the younger adults, we found neither a correlation between the reading span measure and the accuracy in the non-garden-path condition, nor the span measure and the accuracy in the garden-path condition. For older adults, we found weak evidence of a correlation between accuracy in the non-garden-path condition and reading span; however, we found a strong correlation between reading span and accuracy in the garden-path condition: the higher their reading spans, the greater their accuracy. These correlations support the idea that memory differences are the reason that older adults are much less accurate in the garden-path condition, and thus more often rely on good-enough processing. Moreover, the correlations support the idea that reinstantiating the presumably decayed syntactic structure of a sentence is more taxing on memory than reinstantiating the propositional content of a sentence. When a comprehension question can be answered correctly by relying on propositional content, older and younger adults would be expected not to differ in their responses (Experiments 1a and 1b). But when the question requires verbatim recall of the sentence and inspection of the syntactic structure, older adults would be expected to perform worse than younger adults, due to their overall more limited memory spans (Experiments 2 and 3), and poorer recall for the sentences compared to the younger adults (Table 2).

Discussion

Experiment 3 examined the correct interpretation of the subordinate clauses of the garden-path sentences containing RAT verbs. We did this by asking comprehension questions that directly probed the reflexive interpretations of the subordinate verbs. We found that younger adults appear able to answer these questions accurately. Although they were less accurate than in the non-garden-path condition, younger participants were able to answer the question accurately 70% of the time. Older adults, on the other hand, had greater difficulty with the reflexive questions in the garden-path sentences. This tendency is heavily influenced by memory

constraints, as evidenced by the strong correlation of reading span and accuracy in the garden-path sentence condition. The failure on the part of older subjects to establish a coreferential relation between the subject NP of the subordinate clause (e.g., *Anna*) and the coreferential null reflexive object of the subordinate clause verb in Experiment 3 is similar to other evidence that under certain circumstances (e.g., higher memory load) older adults have greater difficulty establishing anaphoric coreference during text processing than do younger adults (Light & Capps, 1986; Morrow, Altieri, & Leirer, 1992).

The results of the reflexive questions also support the contention of Christianson et al. (2001) that reanalysis may terminate before it is completed. A comprehension question of the sort asked here appears to be a critical signal to reanalyze some portions of the sentence. If this is the case, it would indicate that the reader does not always obtain a fully licensed analysis of a sentence during reading, but instead often moves on to subsequent text, satisfied with a partially underspecified, or good-enough, parse. Not until pressed on an issue (e.g., by way of a comprehension question) does the reader fully revise at least certain portions of the initial garden-path parse. In other words, until an explicit signal to examine all parts of the interpretation occurs, the reader will hold onto the good-enough interpretation. An illicit syntactic structure signal apparently is not necessarily enough to spur full reanalysis. Effective signals seem to have more to do with the ultimate interpretation of the sentence. In the experiments reported here, the signal prompting reanalysis (or at least recollection) was the probe question. Without this signal and sufficient memory to retrieve the original information (in this case, syntactic information), the reader will not necessarily attempt full sentence reanalysis.

GENERAL DISCUSSION

The current study investigated the effect of the original, ultimately incorrect interpretation of a garden-path sentence on the representation formed by the end of the sentence, focusing particularly on age-related differences. We found, as did Christianson et al. (2001), that after a garden-path sentence has been read, the original interpretation derived from the initial parse appears to remain, influencing the final interpretation of the sentence as evidenced by the response to a comprehension question. Although the original interpretation of a garden-path sentence is syntactically unlicensed, both older and younger adults were more likely to respond to comprehension questions in a manner indicative of the unlicensed parse. The structure of the sentence (garden path vs. non-garden path) had a large effect on the endorsement rates of the unlicensed interpretation; however, we found no indication of an age interaction with the sentence structure. Both age groups were equally affected by the garden-path structures when it came to answering the comprehension questions. Although we found no age difference in the responses based on the sentence structure of the experimental sentences, we did find that older adults were more likely to respond with a transitive interpretation when the verb in the subordinate clause was an OPT verb. No age differences were found when the subordinate verb was a RAT verb. We suggest that the age difference in responses to the OPT verb sentences could be due to semantically based inference, potentially one of numerous heuristics older adults use while interpreting garden-path sentences to compensate for an age-related decline in working memory. This sort of inference most likely results from a strategy of relying on the propositions constructed during the parse of difficult sentences rather than the verbatim content, which is sufficient for answering comprehension questions normally used in such studies (Christianson et al., 2001).

Originally, we had anticipated that older adults would be more likely to have access to the original interpretation of a garden-path sentence due to decreased inhibitory efficiency (Hasher et al., 1999), which would increase the chance that older adults would respond with the original garden-path interpretation. However, we found no evidence that age interacted with sentence

structure or length of ambiguous region. This age equivalence could be another instance of age invariance for some aspects of language processing. Several other language phenomena have been demonstrated to vary little, if any, with age (Tun & Wingfield, 1993. The fact that both groups of adults responded similarly with the garden-path interpretation may indicate that although there could be competition between the two interpretations from the sentence, there is no attempt by the comprehension system to inhibit the conflicting alternatives, or to compare them, especially if they are not mutually exclusive. In fact, Christianson et al. (2001) found that younger adults would believe both alternative interpretations of a sentence even though this required the sharing of the critical NP. In other words, participants were able to hold on to two interpretations of a sentence without noticing the syntactic conflict involved in doing so as long as both were semantically compatible. Finally, as Experiment 3 suggested, there may be no competing alternative interpretations constructed during the reading of the sentence, at least for older readers with shorter working memory spans. Such readers may simply have an interpretation that is good enough ("Dressing is going on, and the baby is playing in the crib"), and no other alternative is entertained. Therefore, inhibiting an alternative interpretation would not be needed.

An important observation based on the data from Experiment 3 is that if a garden-path sentence is not reanalyzed fully during reading, working memory limitations might prevent a reader from reinstantiating the syntactic structure needed to derive a correct structure. In particular, the correlation data suggest that older adults who are more capable of reconstructing the original syntactic structure of the sentence after a probe question (i.e., those with higher span scores) are more likely to answer correctly the questions probing the licensed interpretation of the subordinate clause. We propose that reinstantiating the syntactic structure of the subordinate clause is necessary to establish coreference between the subject and the null anaphor object of the RAT verb. This reinstantiation appears to tax working memory.

Memory for the propositional content of the sentence (Kaschak & Glenberg, 2004) in addition to any lingering memory for the syntactic structure appears to contribute to the final interpretation of the sentence. The good-enough interpretation Christianson, Ferreira, and colleagues described relies on coherent propositional content that is built up and integrated into an overall interpretation while reading the sentence. If the interpretation is built up piecemeal, as the sentence is incrementally parsed, those propositions established earlier in the parse might not be checked against those established later or against a (partially) revised structure. Consequently, as long as the individual propositions can be integrated into a coherent, plausible, and semantically viable interpretation, normally we have no need to replace the resultant good-enough interpretation with one that is strictly faithful to the input. In this study we found evidence that if the propositional content of a sentence is congruent, a greater tendency exists (especially by older adults) to rely on it. When the propositions cannot be integrated into a coherent interpretation, the likelihood that the reader will reanalyze a garden-path sentence increases.

However, this incongruence does not always succeed in producing a fully licit structure during reading. On some occasions, when the good-enough interpretation is challenged (in our case by questioning the subordinate clause of the garden-path sentence), the reader has to examine his or her interpretation for the entire structure of the sentence. This is a memory-intensive process in which the readers must retrieve or reconstruct, or sometimes both, the syntactic structure of the sentence and revise their interpretations of the propositions being questioned. Because of memory limitations, some individuals will be unable to succeed in this process and thus must rely on the good-enough interpretation for answering the question. The notion that some aspects of the sentence structure are not resolved until the reader is forced to examine them fits well with the claims of Christianson et al. (2001) and Ferreira et al. (2002) that readers abbreviate syntactic reanalysis and hold onto a good-enough interpretation.

Our proposal that older adults have difficulty reconstructing the syntactic structure of a garden-path sentence after reading it and that this leads them to rely on a good-enough propositional structure is consistent with previous research on cognitive aging. Kemper and colleagues (e.g., Kemper, 1986; Kemtes & Kemper, 1997) have demonstrated age-related differences in language processing that appear to be tied to working memory differences. In contrast, Caplan and Waters (1999; Waters & Caplan, 2002) have argued that initial language processing is independent of the resources working memory capacity measures. Our results (like those of Dede et al., 2004) provide a bridge between these studies. First, we found that older adults were similar to younger adults in their responses to the garden-path sentences presented in Experiments 1 and 2. The lack of age differences (with the exception of the age group main effect for OPT verbs) in the effects of the sentence structure, the length of the ambiguous region, and plausibility are all consistent with Caplan and Waters' contention that working memory does not influence language processing. However, the results of Experiment 3 clearly indicate that working memory is critical for accessing the syntactic structure of a sentence to determine the thematic roles of constituents that may not have been correctly analyzed during the initial parse. This result shows a reliance on working memory as Kemper and colleagues have demonstrated. Putting these two findings together, our results support the conclusions of Dede et al. (2004) that little age difference may be found during the initial processing of a sentence, but any processes that require subsequent access of specific structural content will demonstrate age-related working memory differences.

Thus, consistent with other studies (Davidson, Zacks, & Ferreira, 2003; Tun & Wingfield, 1993), this study demonstrates an age invariance in one aspect of language processing; however, this study also demonstrates the importance of examining individual differences in the interaction of memory and language. Our finding that older adults were significantly less able to answer accurately comprehension questions regarding the subordinate clauses of garden-path sentences indicates that full reanalysis of the syntactic structure of these sentences may not happen until the participant is forced to examine specific aspects of an initial good-enough parse.

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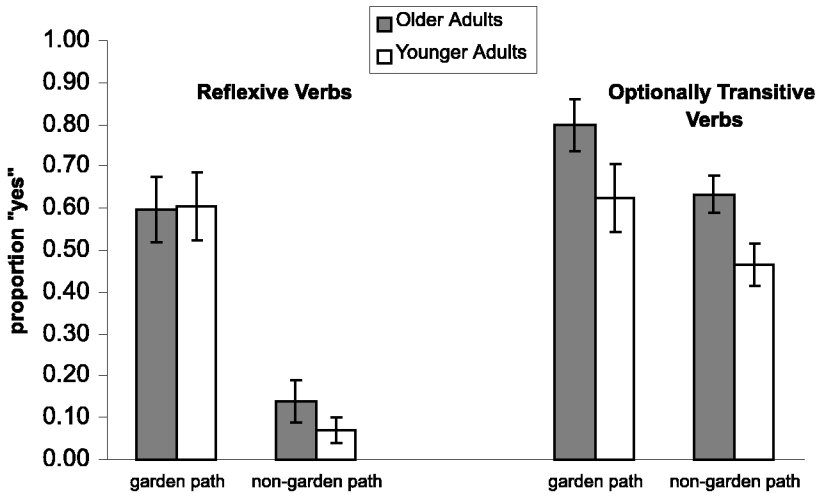

FIGURE 1.
Proportion of unlicensed “Yes” responses to comprehension questions for reflexive and optionally transitive verb sentences in Experiment 1a.

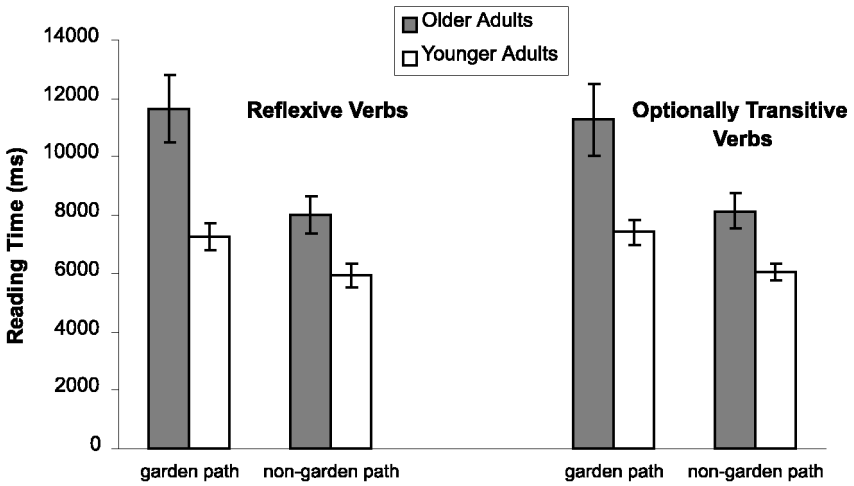

FIGURE 2.

Reading time for reflexive and optionally transitive verb sentences in Experiment 1a. Error bars are standard error of the mean for each condition.

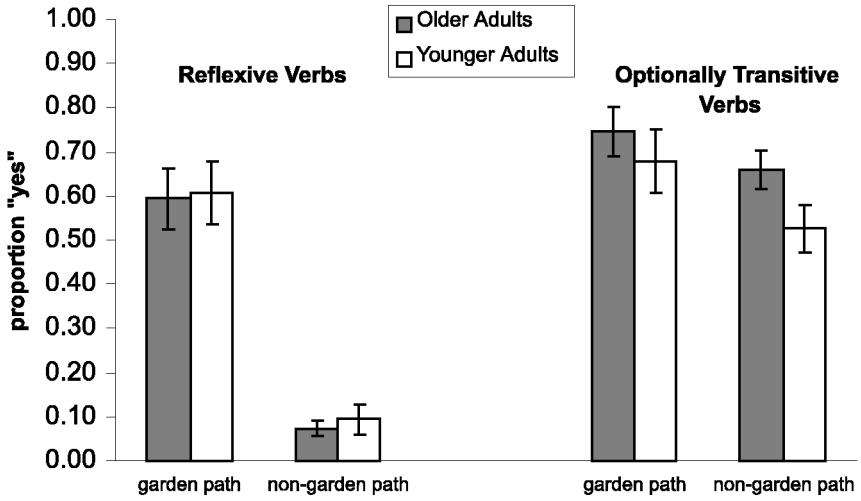

FIGURE 3.
Proportion of unlicensed "Yes" responses to comprehension questions for reflexive verb and optionally transitive verb sentences in Experiment 1b. Error bars are standard error of the mean for each condition.

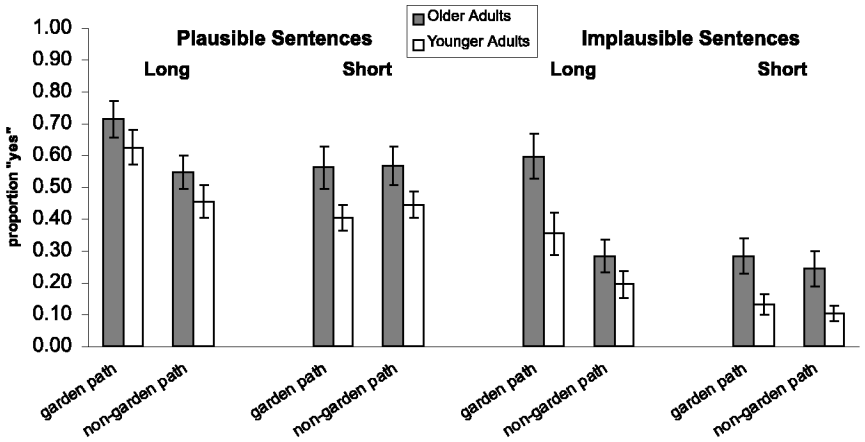

FIGURE 4.
Proportion of unlicensed "Yes" responses to comprehension questions in Experiment 2. Error bars are standard error of the mean for each condition.

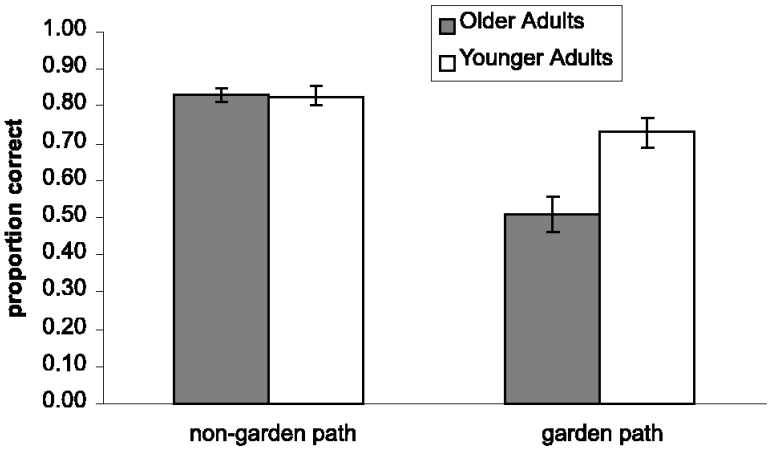

FIGURE 5.
Proportion of *correct responses* to reflexive comprehension questions of reflexive verb sentences in Experiment 3. Error bars are standard error of the mean for each condition.

Table 1

Example Sentences for Experiments 1a and 1b

Optionally transitive verbs
Garden-path structure (subordinate–main clause order)
While the man hunted the deer that was brown and graceful ran into the woods.
Non-garden-path structure (main–subordinate clause order)
The deer that was brown and graceful ran into the woods while the man hunted.
Comprehension question
Did the man hunt the deer?
Reflexive absolute transitive verbs
Garden-path structure (subordinate–main clause order)
While Anna dressed the baby that was small and cute played in the crib.
Non-garden-path structure (main–subordinate clause order)
The baby that was small and cute played in the crib while Anna dressed.
Comprehension question
Did Anna dress the baby?

Table 2

Demographic Means and Standard Deviations for Experiments 1 Through 3

		Age		*Years of Education*		*Vocabulary*		*Reading Span*		*Sentence Memory*	
	N	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Experiment 1a											
Younger adults	24	20.5	2.5	13.8	1.4	29.4	3.1	35.5	5.18	.79	.10
Older adults	24	75.6	6.5	15.0	2.4*	34.9	4.0*	32.9	4.87	.73	.90*
Experiment 1b											
Younger adults	24	20.9	2.0	14.4	1.7	31.1	3.3	38.0	3.88	.84	.60
Older adults	24	74.8	4.4	14.7	2.2	36.1	4.0*	34.3*	5.55	.70	.11*
Experiment 2											
Younger adults	24	22.2	2.9	14.9	1.2	30.0	3.6	36.4	3.88	.78	.80
Older adults	24	73.8	5.7	14.9	2.3	34.8	4.0*	35.0	5.70	.73	.90
Experiment 3[a]											
Younger adults	57	20.5	3.0	13.8	1.5	29.6	3.3	37.5	3.65		
Older adults	59	73.4	5.5	15.1	2.4*	34.7	4.4*	34.1*	5.30		

* $p \leq .05$.

Table 3

Correlations of Reading Span and Comprehension Question Proportion *Yes* for Experiments 1a and 1b (Combined)

	Optionally Transitive Verbs		*Reflexive Absolute Transitive Verbs*	
	Non-Garden Path	***Garden Path***	***Non-Garden Path***	***Garden Path***
Younger adults	−.22	−.19	.01	−.24**
Older adults	−.29*	−.42*	−.26**	−.44*

* $p \leq .05$.

** $p \leq .10$.

Table 4

Example Sentences for Experiment 2

Long ambiguous region
Plausible/implausible
Garden-path structure (subordinate–main clause order)
While the man hunted the deer that was brown and graceful ***ran into the woods/paced in the zoo***.
Non-garden-path structure (main–subordinate clause order)
The deer that was brown and graceful ***ran into the woods/paced in the zoo while the man hunted***.
Short ambiguous region
Plausible/implausible
Garden-path structure (subordinate–main clause order)
While the man hunted the deer ***ran into the woods/paced in the zoo***.
Non-garden-path structure (main–subordinate clause order)
The deer ***ran into the woods/paced in the zoo*** *while the man hunted.*
Comprehension question
Did the man *hunt* the deer?

Table 5

Correlations of Reading Span and Comprehension Question Proportion *Yes* in Experiment 2

	Long Region		*Short Region*	
	Non-Garden Path	***Garden Path***	***Non-Garden Path***	***Garden Path***
Plausible sentences				
Younger adults	−0.01	−0.13	−0.12	−0.16
Older adults	0.06	−0.37**	−0.18	−0.02
Implausible sentences				
Younger adults	−0.15	−0.11	−0.28	−0.11
Older adults	−0.23	−0.43*	−0.26	−0.47*

* $p \leq .05$.

** $p \leq .10$.

Table 6

Correlations of Reading Span and Correct Responses to Comprehension Questions for Experiment 3

	Non-Garden Path	*Garden Path*
Younger adults	.02	.02
Older adults	.21	.48*

* $p \leq .05$.