

Aging effects and working memory in garden-path sentence comprehension

BACKGROUND

How adults resolve and recover from syntactic ambiguity has been a central research topic in the psycholinguistic literature. Understanding how adults comprehend syntactically ambiguous *garden-path sentences* is critical to models of sentence comprehension (Frazier, 1979; McDonald, Perlmutter & Seidenberg, 1994). Furthermore, determining the connection between syntactic ambiguity resolution and cognitive abilities such as working memory may be a possible indicator of healthy cognitive aging effects in studies of sentence comprehension (e.g., Caplan & Waters, 1999).

Recent sentence-comprehension studies examining the effects of healthy aging have compared on-line and off-line performance. Most have reported qualitatively similar on-line performances among older and younger adults. Age-related differences appear primarily in off-line measures like post-sentential comprehension probes (e.g., DeDe, et al., 2004, Stine-Morrow, et al., 2000), and these off-line differences often correlate with measures of working memory like span tasks (e.g., Christianson, et al., 2006). This pattern is consistent with Caplan and Waters' (1999) claim that on-line sentence processing is relatively immune to aging and does not draw on general working memory resources.

However, most of these studies have focused on comprehension of challenging but unambiguous sentences such as relative clauses. In contrast, relatively few studies have examined comprehension of garden-path sentences in aging, where comprehenders initially commit to one interpretation of a temporarily ambiguous sentence but must later revise that interpretation. The few studies examining aging effects on syntactic ambiguity resolution and revision in garden-path sentences report conflicting findings. Kemtes and Kemper (1997) found no age-related differences in self-paced reading for garden-path sentences with a main-verb/reduced-relative ambiguity. However, Kemper, et al. (2004) found that older adults and low-span younger adults had elevated regressions and total reading times in an eyetracking study of similar sentences. This finding suggests that older adults and adults with reduced working-memory capacity may have difficulty in garden-path recovery, i.e. when they must revise a previously-built structure or interpretation (viz. Christianson, et al., 2006; Titone, et al., 2006). The comprehension of garden-path sentences may therefore provide a measure of healthy cognitive aging and its effects on sentence-comprehension performance.

The current study therefore examined whether older adults exhibit difficulty in recovering from syntactic garden paths across sentence types, and whether this difficulty is predicted by working memory capacity. The main research questions for this study are as follows:

1. Does each age group (younger and older adults) show garden-path effects during comprehension of syntactically ambiguous sentences?
2. Is the magnitude of the garden-path effect in elderly adults significantly different from the effect in young adults?
3. Is the magnitude of garden-path effects (among either older or younger adults) predicted by measures of working memory (WM)?

METHODS

Older adults (n=35, ages 60-89) and younger adults (n=36, ages 19-30) completed two self-paced reading experiments and a battery of cognitive measures. All adults passed screening tests designed to exclude the presence of dementia and reported no history of such disorders. WM was assessed using sentence-span (Waters & Caplan, 2003), forward- and backward-digit span, and subtract 2 span tasks. Participants read 20 sentences containing a Minimal Attachment reduced-relative/main-verb ambiguity in Experiment 1 (1a-b), and 24 sentences containing a Late Closure ambiguity in Experiment 2 (2a-b).

- (1) a. The editor | played | the tape | and | agreed | the story | was big.

b. The editor | played | the tape | agreed | the story | was big.
(Stimuli taken from Ferreira & Clifton, 1986; | indicates presentation regions)

- (2) a. While | the man | hunted | the pheasant | the deer | ran | into | the woods.
b. While | the man | hunted | the deer | ran | into | the woods.
(Stimuli taken from Christianson, et al., 2001; | indicates presentation regions)

Each sentence was followed by a forced-choice acceptability judgment. The rejection rate was computed for both conditions; higher rejection rates in conditions (1b/2b) are indicative of a garden-path effect.

RESULTS

Reading times for the disambiguating verb (underlined) were longer in the garden-path condition (1b/2b) in Experiments 1 and 2 for both groups ($ps < .001$). This indicates that both groups experienced a garden-path effect during their comprehension of garden-path sentences, in on-line measures. Older participants also exhibited longer reading times than younger participants in both experiments ($ps < .001$).

Importantly, the magnitude of the garden-path effect (the difference between garden-path and non-garden-path conditions) was greater for older than younger participants in both experiments ($ps < .05$). This indicates that older adults experienced a larger garden-path effect than younger adults, specifically at the point where they encountered material (a verb) indicating that they must revise their initial interpretation of the sentence. In contrast to this on-line difference, older participants showed a smaller difference between garden-path and non-garden-path conditions in end-of-sentence acceptability judgments for both experiments ($ps < .05$).

Regression analyses showed that the size of the older participants' garden-path effects at the disambiguating verb was predicted by sentence-span performance in Experiment 1, and by a combined model involving all cognitive measures in Experiment 2. This indicates that older adults' comprehension of garden-path sentences (and more specifically, the penalty they experience when they must revise their interpretation of a sentence) may be affected by their WM capacity.

DISCUSSION AND CONCLUSIONS

This study found several points. First, there was a garden-path effect regardless of age group. This suggests that both groups experience a penalty when they must revise their initial interpretation of a syntactically-ambiguous garden-path sentence. Second, there were age-related differences for the sentences with temporary syntactic ambiguity in on-line and off-line measures among young and elderly adults. This finding indicates that not the existence but *the magnitude of the garden-path effect* is affected by aging. Third, the aging effect – more specifically, the magnitude of the reading-time penalty for older adults – is predicted by WM. Together, these points suggest that there is a connection between syntactic ambiguity resolution and WM, at least among older adults (viz., Christianson, et al., 2006).

These findings are consistent with previous off-line results suggesting that older adults have greater difficulty revising a sentence's structure and interpretation than younger adults (Titone, et al., 2006). They also suggest that successful on-line revision may be related to working memory capacity (Christianson, et al., 2006). Furthermore, they indicate that on-line processes may indeed be affected by normal aging and by working memory - at least for reanalysis - when comprehenders must revise representations maintained in memory (contra Caplan & Waters, 1999). These data may therefore serve as a baseline for estimating the effects of healthy cognitive aging on sentence comprehension, to help distinguish the effects of healthy aging from those of dementia and other conditions, including aphasia.

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