GARDEN-PATH EFFECTS AND RECOVERY IN APHASIA

BACKGROUND

How people resolve and recover from syntactic ambiguity has been a central research topic in the psycholinguistic literature on sentence comprehension. It has attracted less attention in the literature on communicative impairments. However, there is increasing evidence that brain damage can affect how adults understand syntactically ambiguous sentences, both for right-hemisphere brain damage (e.g., Schneiderman & Saddy, 1988) and left-hemisphere damage (e.g., Novick, Trueswell & Thompson-Schill, 2005). Understanding how persons with aphasia (PWA) comprehend syntactically ambiguous sentences is therefore important to evaluating their communicative function, specifically their sentence comprehension ability.

Syntactically ambiguous sentences are often referred to as garden-path sentences (Bever, 1970). These sentences lead comprehenders "down the garden path": they cause readers or listeners to briefly misinterpret an ambiguous word or phrase, initially misanalyzing its syntactic role in the sentence. Subsequent information then indicates that this initial interpretation was incorrect, forcing comprehenders to reinterpret the sentence. This garden-path effect has been consistently found in healthy young and older adults (Christianson, et al., 2001, 2006; Ferreira & Henderson, 1991; Frazier & Rayner, 1982).

Syntactic ambiguity resolution may be particularly strongly affected by reduced cognitive function such as reduced working memory (WM), common in healthy aging (e.g., Christianson, et al., 2006; Kemper et al., 2004). Kemper and colleagues (2004) found that older adults showed larger garden-path effects than younger adults, spending longer reading and re-reading garden-path sentences, and that these age-related differences were mediated by WM. This finding provides evidence of the importance of WM in resolving syntactic ambiguities. Christianson, et al. (2006) found that older adults' comprehension question accuracy for garden-path sentences was correlated with their WM span. This finding provides evidence of the role of WM in successful recovery from a garden path.

However, there has been little research on whether PWA also exhibit garden-path effects in their real-time comprehension of syntactically ambiguous sentences, or how successfully they recover from such garden paths. PWA have also been argued to have reduced WM capacity which contributes to their sentence comprehension deficits (e.g., Miyake, Carpenter & Just, 1994). WM is likely involved in the reanalysis of garden-path sentences (Kemper, et al., 2004), since reanalysis requires performing operations on structures held in memory. This study therefore examined the comprehension of garden-path sentences in PWA, and tested how their on-line garden-path effects and their off-line garden-path recovery were predicted by WM and short-term memory (STM).

METHODS

PWA (N=8, mean age: 55.6; range: 42-67) passed screening tests (Western Aphasia Battery-mean WAB AQ: 81.25, Raven's Colored Progressive Matrices, the Arizona Battery for Communication in Dementia – see Table 1) and completed two self-paced reading experiments with two different sentence-final tasks (Experiment 1: acceptability judgments; Experiment 2: comprehension questions). There was at least a 6 month gap between the two experiments for all participants. Participants also completed a battery of cognitive measures (see Table 2), including measures of STM (forward digit span) and WM (backward digit span).

<u>On-line language processing measures</u>: Participants read 20 sentences like (1a-b) (along with 80 fillers) in self-paced moving window format on a laptop computer. Garden-path conditions (1b) violated the Minimal Attachment preference (Frazier & Rayner, 1982) for a main-verb interpretation of the initial verb ('played'). Participants pressed the space bar to read each segment of the sentence and reveal the next segment.

(1) a. The editor | played | the tape | and | <u>agreed |</u> the story | was big. *Non-garden-path*
   b. The editor | played | the tape | <u>agreed |</u> the story | was big. *garden- path*
   (Stimuli taken from Ferreira & Clifton, 1986; | indicates presentation regions)

Reading times for the second verb (*agreed*) provide a measure of the garden-path effect. Specifically, they measure the degree to which participants are disrupted by information inconsistent with their initial analysis of the sentence in the garden-path condition (1b).

<u>Off-line language processing measures</u>: For each sentence, participants provided a sentence-final response. They provided an acceptability judgment in Experiment 1 (2a) and answered a comprehension probe in Experiment 2 (2b).

(2) a. Acceptability judgment: Acceptable?
   b. Comprehension probe: Did the editor play the tape?

Accuracy for acceptability judgments (Ferriera & Henderson, 1991, 1993) and comprehension probes (Christianson, et al., 2001, 2006) provide a measure of successful recovery from the garden path.

RESULTS
In on-line measures, PWA exhibited a garden-path effect for both Experiment 1 and 2. Reading times for the second verb (underlined) were significantly longer in the garden-path condition (1b) than the non-garden path (control) condition (1a) in both Experiments 1 ($p<.001$) and 2 ($p<.05$). This reading-time difference suggests that PWA were lead down the garden path when comprehending syntactically ambiguous sentences, much like healthy older and younger adults.
    In off-line measures, there was a significant mean difference in accuracy between the control and garden-path conditions for the comprehension probes in Experiment 2 ($p<.05$), with participants being less accurate in the garden-path condition (see Figure 2 and 4). However, there was no significant mean difference in acceptability judgments between control and garden-path conditions for acceptability judgments in Experiment 1. This difference suggests that the different sentence-final tasks influenced how successful PWA were in their garden-path recovery.
    There was also a relationship between the size of garden-path effects (reading times on the critical verb in the garden-path condition versus control condition) and some cognitive measures. Performance on STM measures was correlated with the size of garden-path effects, but only in Experiment 1 ($r=.79$, $p<.05$). WM measures were not correlated with the size of garden-path effects in either experiment. Sentence-final task performance was not correlated with WM or STM measures for either Experiment 1 or 2.

DISCUSSION AND CONCLUSIONS
PWA exhibited on-line garden-path effects in their comprehension of sentences with temporary syntactic ambiguities in both Experiments 1 and 2. This effect appeared in the form of elevated

reading times on the critical word of garden-path conditions (see Figure 1 and 3). This finding may be taken as evidence that PWA experience a penalty when they must revise their initial interpretation of a syntactically-ambiguous garden-path sentence, much like healthy older adults (Kemper, et al., 2004). However, in contrast to patterns seen for healthy older adults, WM was not associated with either on-line reading times for garden-path sentences (cf. Kemper, et al., 2004) or off-line task performance (cf. Christianson, et al., 2006). Furthermore, PWA were often unsuccessful in their garden-path recovery, as indicated by their lower comprehension-probe accuracy for garden-path conditions in Experiment 2. These findings suggest that the garden-path effects for PWA may not have been indicative of successful reanalysis, unlike for healthy older adults.

One possible explanation for this pattern is that PWA were able to detect the mismatch between the critical word and the preceding structure in the garden-path condition, but were not able to revise the preceding structure (viz. DeDe, 2013; Titone, et al. 2006). Consistent with this explanation is the finding that STM (not WM) was correlated with the size of the garden-path effect. PWA with sufficient STM capacity were able to detect the mismatch between the critical word and preceding material.

In addition, there were task effects in off-line performance (accuracy differences between Experiments 1 and 2) and in the relationship between on-line measures and STM measures (found for Experiment 1 only). These differences indicate that PWAs' comprehension performance for garden-path sentences may vary, depending on the task (viz. Linebarger, Schwartz & Saffran, 1983).

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Titone, D.A., Koh, C.K., Kjelgaard, M.M., Bruce, S., Speer, S.R. & Wingfield, A. (2006). Age-related impairments in the revision of syntactic misanalyses: Effects of prosody. *Language & Speech, 49(Pt1*), 75-99.

Table 1. Demographic and lesion information for all patients in experiments 1 and 2

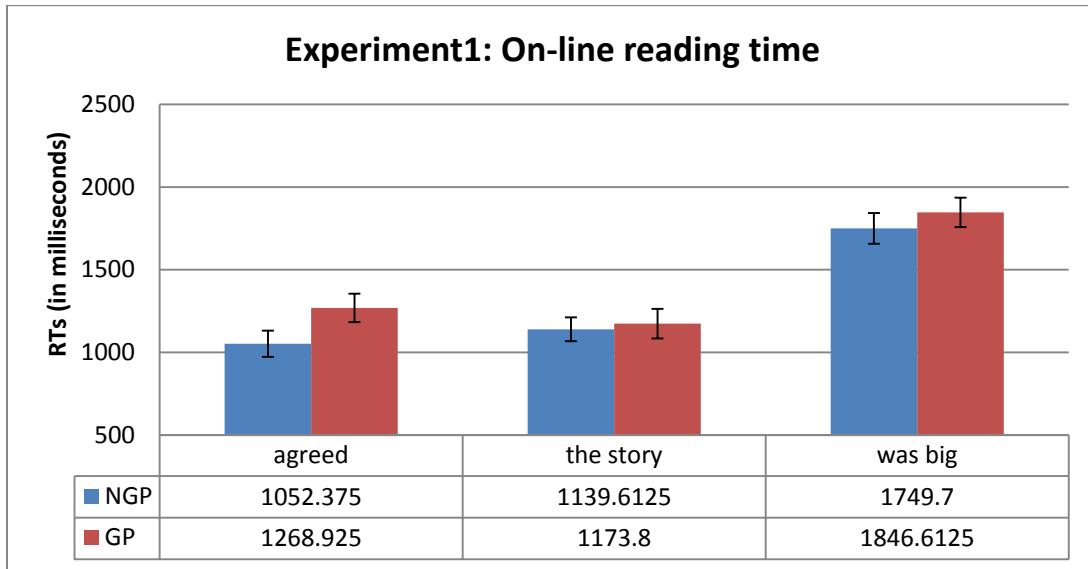| Patient	AQ	Gender	Age	TPO*	Education (in years)	Lesion	Aphasia type
101	77	F	67	2 y 1 w	12	Infarction extends fully into L MCA territory including L insula, L frontal operculum, posterior L frontal lobe	Anomic
103	75.3	M	42	6 y 8 m 2 d	17	Left frontal/temporal/parietal	TCM**
104	70.3	M	63	8 y 3 m	14	Left frontal, left occipital, left temporal	Conduction
105	55.2	M	51	3 y	12	Left MCA distribution involving posterior L frontal lobe, anterior L parietal lobe, and L basal ganglia	Broca's
107	52.6	F	47	4 y 5 m 1w	16	Left MCA*** distribution involving L frontal, parietal, and anterior temporal lobes	Broca's
108	88.9	M	61	4 m	12	Focal infarct L posterior frontal; old infarct L MCA territory: L frontoparietal	Anomic
110	90.6	M	48	2 y 7 m 3 d	14	unknown	Anomic
112	85.5	F	66	4 y 7 m 12 d	15	unknown	Anomic

TPO*: Time post onset
TCM**: Transcortical motor aphasia
MCA***: Middle cerebral artery

TABLE 2. Screening test results and Cognitive measures: Working Memory (WM) & Short Term Memory (STM) for PWA

	Number of Subjects	Raven's (Max=36)		ABCD (Ratio Dealyed: Immediate recall)		STM Digit span Forward (% of correct response)		WM Digit span Backward (% of correct response)	
	N	M	SD	M	SD	M	SD	M	SD
PWA	8	28.63	7.56	1.06	.21	65.39	6.5	56.64	0.97

FIGURE 1. Reading times in milliseconds for *critical word* (Experiment 1: acceptability judgment task).

Experiment1: On-line reading time

	agreed	the story	was big
NGP	1052.375	1139.6125	1749.7
GP	1268.925	1173.8	1846.6125

NGP: Non-garden-path (control) condition
GP: Garden-path condition

FIGURE 2. Acceptability rate (% YES responses) (Experiment 1).

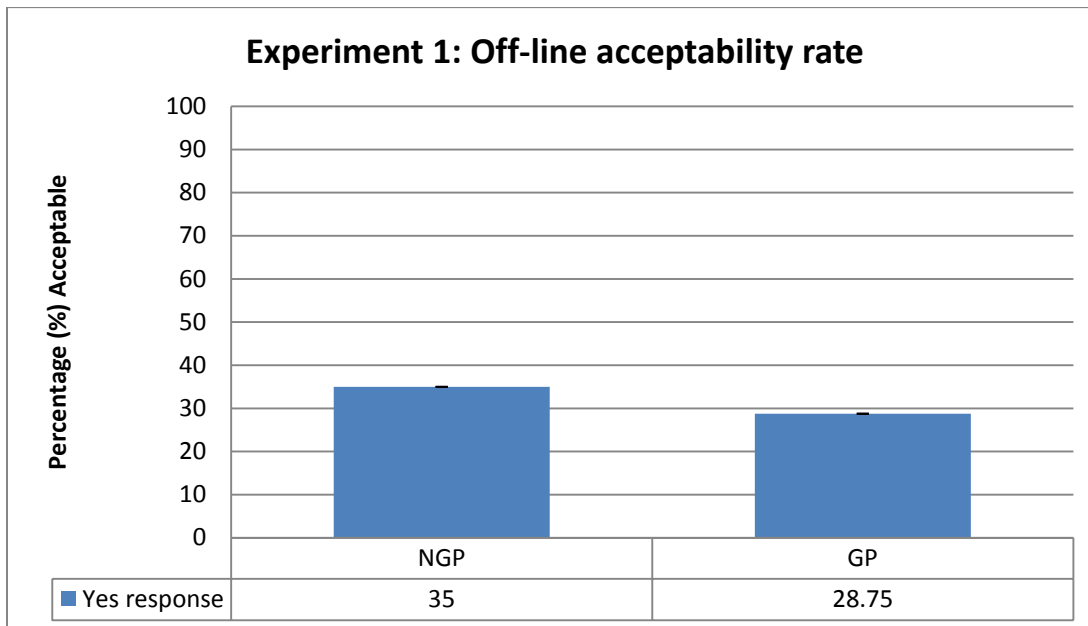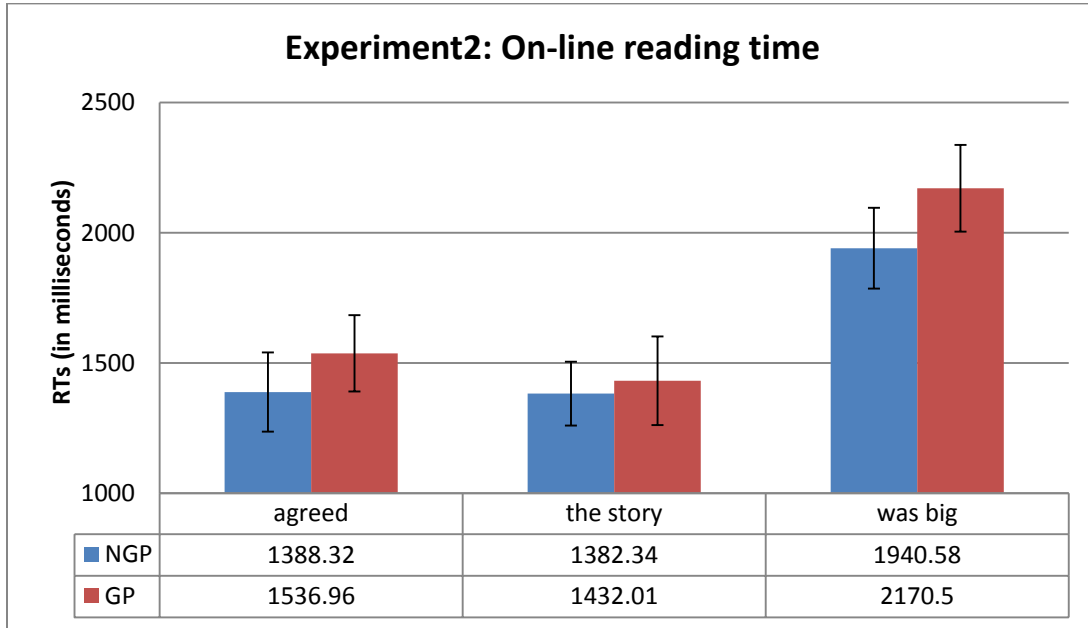**Experiment 1: Off-line acceptability rate**

	NGP	GP
Yes response	35	28.75

FIGURE 3. Reading times in milliseconds for *critical word* (Experiment 2: comprehension probes).

Experiment2: On-line reading time

	agreed	the story	was big
NGP	1388.32	1382.34	1940.58
GP	1536.96	1432.01	2170.5

NGP: Non-garden-path (control) condition
GP: Garden-path condition

FIGURE 4. Comprehension probe accuracy (% YES responses) (Experiment 2).

Experiment 2: Off-line comprehension probes accuracy

	NGP	GP
Yes response	80	25