The on-line comprehension of wh- movement structures in agrammatic Broca's aphasia: Evidence from eyetracking

Abstract

Dickey & Thompson (2004) present evidence that individuals with agrammatic Broca's aphasia retain significant on-line gap-filling capacity, which improves in response to linguistically-motivated treatment (TUF; Thompson 2001). This paper presents data from an eyetracking study following up this result. Twelve agrammatic aphasic individuals' and eight control participants' eyes were tracked while they listened to stories ending with comprehension probes involving wh- movement (wh- object questions, object clefts). Aphasic participants' responses to probes demonstrated impaired comprehension of wh- movement structures. However, their eye-movements indicated intact automatic processing of the movement sentences, even for wh-questions which they failed to comprehend.

Background and rationale

Individuals with agrammatic Broca's aphasia have problems comprehending sentences with movement like (1a-b) (Caramazza & Zurif 1976, among others).

(1) a. Who$_i$ did the boy kiss t_i today at school?
b. It was the girl$_i$ who$_i$ the boy kissed t_i today at school.

Under standard linguistic analyses (Chomsky, 1986, 1995), both these structures involve wh-movement. The wh- question word "who" in (1a) and the NP "the girl" in (1b) (or the wh-operator "who" coreferent with it) have moved to their non-canonical surface positions, with a trace (t) occupying their object position following the verb "kiss(ed)." Dickey & Thompson (2004) present evidence regarding the on-line comprehension of such wh- movement sentences by agrammatic aphasic individuals. Using an auditory anomaly detection paradigm, Dickey & Thompson found that some agrammatic aphasic patients were able to associate a moved element with a gap or trace following a verb (and reject the sentence as "not making sense" if appropriate) within 2000 milliseconds of hearing the verb. Further, linguistically-motivated treatment (TUF; Thompson 2001) appeared to improve on-line comprehension of these sentences: agrammatic aphasic participants who had received such treatment were faster and more accurate in their responses to these sentences than patients who had not.

The current study follows up these results by examining the comprehension of wh-movement structures by agrammatic aphasic individuals using an even more sensitive methodology, eyetracking. This methodology provides a continuous measure of sentence comprehension, based on how quickly participants fixate on pictures corresponding to different elements in the sentence (such as the agent and patient of the verb). Previous results using this paradigm with young unimpaired participants (Sussman & Sedivy 2003) has found that typical

comprehenders show visual evidence of gap-filling in wh- questions: when listening to a wh-question like (1a), participants look to a picture corresponding to the moved element (the person kissed) upon hearing the verb ÒkissÓ(which licenses the trace). If agrammatic aphasic individuals are able to process the movement dependency in wh- questions, they should also show such visual evidence of gap-filling.

Methods

Participants. Twelve individuals with agrammatic BrocaÕs aphasia (three female) and eight healthy age matched individuals (five female) served as participants. The agrammatic participants were all mildly to moderately impaired, as assessed by the Western Aphasia Battery (Kertesz 1982), with the exception of one participant who exhibited severe apraxia of speech. Their mean WAB AQ was 67.6 (range: 30 — 89.5); they were between 1 and 21 years post-onset and between 34 and 78 years of age at the time of testing. All aphasic participants showed impaired comprehension and agrammatic production: their speech lacked grammatical morphology and was non-fluent. The control participants were between 34 and 67 years of age. All participants were premorbidly right-handed, well educated, native monolingual speakers of English and demonstrated good visual and hearing acuity.

Stimuli and procedures. Participants listened to brief stories like (2) below over a loudspeaker. Each story ended with a beep and was followed by either a simple wh- question (2a), an object cleft (2b), or a yes-no question (2c).

(2) This story is about a girl and a boy.

One day, they were playing at school.

The girl was pretty, so the boy kissed the girl.

They were both embarrassed after the kiss.

a. Who did the boy kiss that day at school?
b. It was the girl that the boy kissed that day at school.
c. Did the boy kiss the girl at school that day?

Each story was accompanied by a visual display with pictures depicting the critical sentence's subject (the boy in (2)), object (the girl), location (the school), and an inanimate distractor not mentioned in the story (e.g., a door). Participants were instructed to respond aloud to the final sentence, either answering the question (for wh- and yes-no questions) or judging the sentence true or false (for object clefts). Participants heard 30 experimental stories like (2) and 20 fillers while their eye movements were recorded by an ASL model 504 remote eyetracker with pan/tilt optics. The position of each participant's gaze was sampled once every 16 milliseconds. Responses to comprehension question were recorded by hand.

Results

Control participants exhibited good comprehension of all three comprehension probe types, with all participants exhibiting 90% accuracy or higher for each of the probe types. The aphasic participants were more impaired in their comprehension of sentences with wh-movement than sentences without it. Accuracy for yes-no questions (86.7%) was significantly better than chance (t=10.32, p<0.001, SD=0.123), while accuracy for the two wh- movement sentence types was not significantly better than chance (70% for wh- questions: t=2.08, p<0.07, SD=0.333; 66.7% for object clefts: t=1.93, p<0.09, SD=0.299).

Eye-movement patterns (Figure 1) revealed that control participants looked to the object (the girl) more often than the subject (the girl) starting at the gap region of the wh- question (from offset of verb to onset of locative PP, underlined in (2): (t = 3.88, p=0.005, SD=0.124). It

is during this part of the sentence that participants encounter the position from which the wh-element was moved. This result is parallel to Sussman & Sedivy's (2003) findings for young, unimpaired listeners. Aphasic participants showed visual evidence of gap-filling for wh-questions which they answered correctly (Figure 2), with more looks to the object picture than the subject picture starting at the verb ($t=3.98, p<0.005$, SD=0.118). This is even earlier than control participants. Aphasic participants also showed more object than subject looks during the gap region for wh- questions which they answered incorrectly (Figure 3). However, this pattern was reversed at the location region, with more subject than object looks (significant interaction of sentence region and object fixated; $F[2,14]=3.81$, $p<0.05$, MSe=0.067). This pattern is indicative of successful reactivation of the moved element following the trace, followed by additional incorrect fixations.

Discussion

These results demonstrate a tight connection between on-line performance in eyetracking tasks and off-line sentence comprehension, even in disordered populations. Correctly and incorrectly comprehended sentences showed qualitatively different patterns of fixations and automatic processing. This suggests that eyetracking can be useful as an on-line measure of linguistic deficits and recovery. Further, the data indicate that individuals with aphasia can show visual evidence of successful automatic gap-filling, even for incorrectly comprehended sentences. In addition, the visual evidence of gap-filling appeared just as early for aphasic participants as it did for controls. These data thus provide converging evidence that some aphasic individuals may retain some gap-filling capacity (cf. Love, Swinney & Zurif 2001) which may be stimulated by treatment (Dickey & Thompson, 2004).

References

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Figure 1: Proportion of fixations while listening to wh-questions, to either the pictured subject or object at critical sentence regions (V (verb), Gap site, or Location (prepositional phrase)) for control participants.

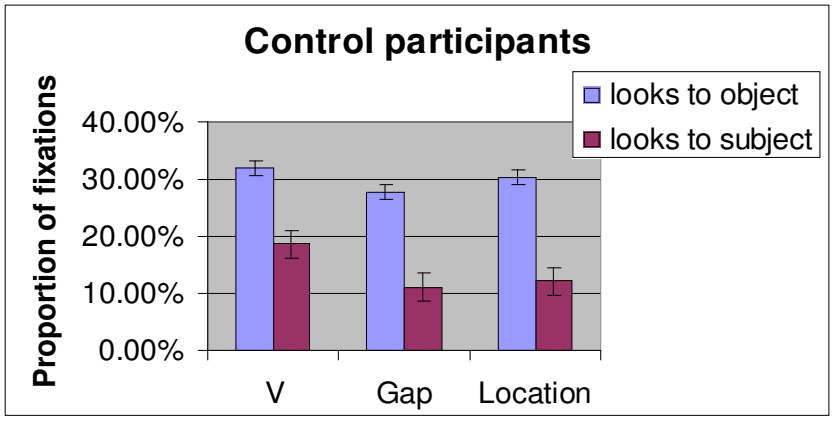

Figure 2: Proportion of fixations while listening to wh-questions, to either subject or object at critical sentence regions (V (verb), Gap site, or Location (prepositional phrase)) for aphasic participants, correct responses only.

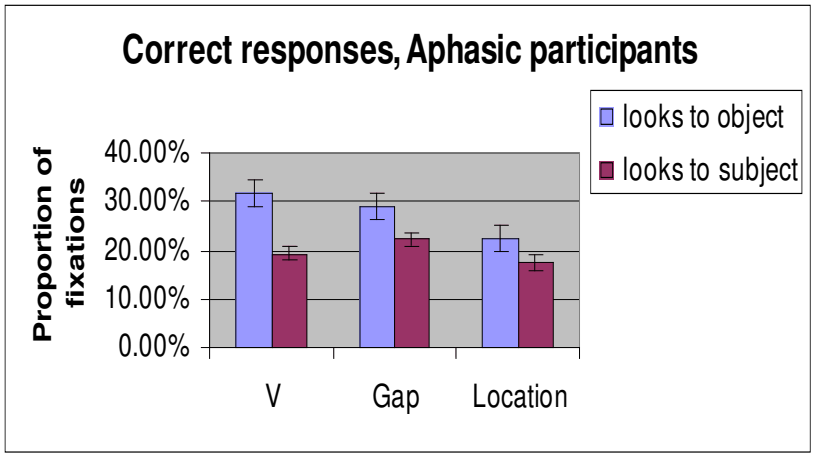

Figure 3: Proportion of fixations while listening to wh-questions, to either subject or object at critical sentence regions (V (verb), Gap site, or Location (prepositional phrase)) for aphasic participants, incorrect responses only.