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The comprehension of sentences with unaccusative verbs in aphasia: a test of the intervener hypothesis

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Abstract

Background—It is well accepted that individuals with agrammatic Broca's aphasia have difficulty comprehending some sentences with filler-gap dependencies. While investigations of these difficulties have been conducted with several different sentence types (e.g., object relatives, *Wh*-questions), we explore sentences containing unaccusative verbs, which arguably have a single noun phrase (NP) that is base-generated in object position but then is displaced to surface subject position. Unaccusative verbs provide an ideal test case for a particular hypothesis about the comprehension disorder—the Intervener Hypothesis—that posits that the difficulty individuals with agrammatic Broca's aphasia have comprehending sentences containing filler-gap dependencies results from similarity-based interference caused by the presence of an intervening NP between the two elements of a syntactic chain.

Aim—To assess a particular account of the comprehension deficit in agrammatic Broca's aphasia—the Intervener Hypothesis.

Methods & Procedures—We used a sentence–picture matching task to determine if listeners with agrammatic Broca's aphasia (LWBA) and age-matched neurologically unimpaired controls (AMC) have difficulty comprehending unaccusative verbs when placed in subject relative and complement phrase (CP) constructions.

Outcomes & Results—We found above-chance comprehension of both sentence constructions with the AMC participants. In contrast, we found above-chance comprehension of CP sentences containing unaccusative verbs but poor comprehension of subject relative sentences containing unaccusative verbs for the LWBA.

Conclusions—These results provide support for the Intervener Hypothesis, wherein the presence of an intervening NP between two elements of a filler-gap dependency adversely affects sentence comprehension.

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Keywords

Aphasia; sentence processing; syntax; neurolinguistics

This article describes an investigation of an account of the sentence comprehension impairment in agrammatic Broca's aphasia—the Intervener Hypothesis. Briefly here and elaborated in a subsequent section, an intervener is a noun phrase (NP) that is placed between two elements of a filler-gap dependency (a type of a syntactic dependency), which can result in processing interference if the NPs in the sentence are structured similarly. Before we detail our hypothesis, we first describe the linguistic background to our study, and then describe some investigations of sentence comprehension in aphasia that form the theoretical background to our work.

Linguistic background

Research has demonstrated that some individuals with agrammatic Broca's aphasia have difficulty understanding sentences containing filler-gap dependencies; that is, sentences where one element in a structure co-refers with another element. Investigations of this difficulty have included a variety of sentence types including, for example, object-extracted relative clauses, *Wh*-questions and passives (e.g., Caramazza & Zurif, 1976; Drai & Grodzinsky, 2006; Grodzinsky, 1990; and many others). One type of filler-gap dependency that has not been the focus of prior investigations involves sentences containing non-alternating unaccusative verbs. Unaccusatives are one-argument (intransitive) verbs; consider:

- (1) The boy disappeared <the boy>.
- (2) The boy slept.

According to the Unaccusativity Hypothesis, in (1)—the unaccusative case—the single argument NP (*the boy*) has been base-generated in object position after the verb and then displaced (i.e., “moved”) to the subject position occurring before the verb (Burzio, 1986; Perlmutter, 1978; Perlmutter & Postal, 1984). In linguistic terms, the NP that is displaced (*the boy*) is the “antecedent” and is copied at the underlying position and then deleted from the surface representation (Chomsky, 1981, 1995). In psycholinguistic terms, the displaced NP is the “filler” and the position from where it was displaced is the “gap”, forming a filler-gap dependency between the two positions. Unaccusatives can be compared to intransitive unergative verbs. In the unergative case (2), the single argument is base-generated in subject position and thus no displacement is involved.

Unaccusatives and unergatives are also distinguished by the thematic roles they assign to their single argument. In the unergative case (2), the single argument (*the boy*) performs the action of “sneezing” and is thus assigned an Agent role. In the unaccusative example (1), the single argument is not responsible for the action but is in fact the recipient of the action, hence assigned the role of Theme. In English, there are two types of unaccusative verbs, alternating and non-alternating. Alternating unaccusative verbs can be used both transitively

and intransitively. For example, the verb *broke* can be used transitively as in (3) and intransitively as in (4).

(3) The boy broke the bowl.

(4) The bowl broke <the bowl>.

In (3) the verb *broke* occurs in a transitive context with two arguments, a subject NP (*the boy*) that is assigned the thematic role of Agent and an object NP (*the bowl*) that is assigned the thematic role of Theme. In (4) the verb *broke* occurs in an intransitive context and thus requires only one argument, which, again, is base-generated in object position and is displaced to surface subject position. The single argument (*the bowl*) is assigned the thematic role of Theme.

Non-alternating unaccusative verbs do not allow for this alternation in transitivity. For example, the verb *disappear* can only be used intransitively as shown in (5) and (6) below (note the * represents an ungrammatical construction).

(5) *The boy disappeared the bowl.

(6) The boy disappeared.

In (5) the verb *disappear* occurs in a transitive context with two arguments, but the verb *disappear* is a non-alternating unaccusative verb. Non-alternating unaccusative verbs only take a single argument and thus (5) is ungrammatical. In (6) the verb *disappear* occurs in an intransitive context with only a single argument and thus results in a grammatical sentence.

The Unaccusativity Hypothesis—that unaccusatives have base-generated objects that move to subject position—has its detractors; there has been considerable effort suggesting that the distinction between unaccusatives and unergatives is best described in semantic and not syntactic terms (see Dowty, 1991; Rappaport Hovav & Levin, 2001; Van Valin, 1990). Even so, there is considerable processing evidence that sentences containing unaccusatives show reactivation of the displaced NP at the post-verb direct object position but unergatives do not. For example, Friedmann, Taranto, Shapiro, and Swinney (2008) investigated the real-time processing of sentences containing unaccusative and unergative verbs. They found reactivation of the displaced single argument of non-alternating unaccusative verbs at a post-verb position, but no reactivation of the single argument of unergative verbs. If unaccusative verbs do not involve a filler-gap dependency, reactivation of the displaced argument would not have been observed, similar to what was found for the unergative verbs (see also Koring, Mak, & Reuland, 2012).

Investigations of the sentence comprehension impairment in agrammatic Broca's aphasia

The few studies have examined the comprehension of sentences containing unaccusative verbs in listeners with agrammatic Broca's aphasia (LWBA) have found comprehension to be intact. For example, Lee and Thompson (2004) tested LWBA in an off-line truth-value judgement task with sentences containing alternating unaccusative verbs in intransitive constructions (e.g., The snowman is melting) and revealed 95% accuracy. Another study by

McAlister, Bachrach, Waters, Michaud, and Caplan (2009) tested LWBA in a sentence–picture matching task and used alternating unaccusative verbs in transitive (e.g., “The dog is rolling the ball”) and intransitive (e.g., “The dog is rolling”) constructions. The image of the opposite alternation of the verb served as the foil (e.g. transitive alternation served as foil for the intransitive alternation). They found 86% correct for the intransitive constructions and 99% correct for the transitive constructions. A study by Piñango (2000) tested two LWBA on a sentence–picture matching task using alternating and non-alternating unaccusatives (e.g., The girl fell because of the boy). Both participants exhibited 93% correct comprehension of sentences containing non-alternating unaccusatives and above chance (100% correct and 80% correct) comprehension of sentences containing alternating unaccusatives. Given the pattern of results across these studies, it does not appear that individuals with agrammatic Broca’s aphasia have difficulty comprehending sentences containing unaccusative verbs.

The intervener hypothesis

The patterns of comprehension in the studies described above are in contrast to the patterns of comprehension impairments in LWBA with sentences containing other types of filler-gap dependencies. There have been several accounts posited to explain why individuals with agrammatic Broca’s aphasia evince these deficits. For example, the *trace deletion hypothesis* claims that LWBA cannot represent traces and are therefore unable to assign thematic roles to displaced NPs (e.g., Drai & Grodzinsky, 2006). The *delayed lexical activation hypothesis* claims that a delay in lexical activation results in de-synchronisation of lexical access and syntactic systems (Ferrill, Love, Walenski, & Shapiro, 2012; Love, Swinney, Walenski, & Zurif, 2008). The *slow syntax hypothesis* claims that syntactic operations are slow, but unimpaired (Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008). Thompson and colleagues also suggest that syntactic operations are unimpaired, but that the *integration of lexical items* is impaired (Choy & Thompson, 2010). Caplan and colleagues suggest that these deficits arise due to a *reduction in processing resources and variability* (Caplan, Waters, DeDe, Michaud, & Reddy, 2007). In our investigation, we examine a relatively new account of the comprehension disorder—the *Intervener Hypothesis*—which proposes that when the displacement of an NP crosses over another argument, comprehension deficits that are a hallmark of agrammatic Broca’s aphasia occur (see Friedmann & Gvion, 2012; Friedmann & Shapiro, 2003; Sheppard, Walenski, Love, & Shapiro, 2015). Consider:

(7) The man saw the boy that **the girl** kissed <the boy> behind the bleachers.

The NP—*the boy*—has been displaced from its underlying direct object argument position to a position occurring earlier in the sentence, leaving behind a copy that is deleted from the representation or a gap (in psycholinguistic terminology). Note that the displaced NP crosses over an intervening argument position occupied by the subject NP *the girl* (boldfaced above). Both the intervener and the filler are fully realised lexical NPs that result from the merging of a Determiner and Noun. The intuition here is that the intervening NP interferes with computing the dependency relation between the displaced NP and its gap, rendering a processing disadvantage of such structures over those that do not contain an intervener. Some adults with a language disorder may be particularly vulnerable to interveners during

sentence processing, perhaps because they are susceptible to interference among similarly structured NPs. This hypothesis, grounded in the linguistic (e.g., Rizzi, 2004) and psycholinguistic literatures (Gordon, Hendrick, & Johnson, 2004; Gordon, Hendrick, Johnson, & Lee, 2006), has also been suggested in previous investigations of the comprehension deficits in agrammatic Broca's aphasia (Friedmann, 2008; Friedmann & Gvion, 2012; Friedmann & Shapiro, 2003; Grillo, 2005, 2009).

Recent findings support the Intervener account. Sheppard et al. (2015), in an eye tracking-while-listening study, presented the following *Wh*-questions to LWBA—the same participants tested in the present study—while they viewed a three-figure picture (e.g., a mailman pushing a fireman pushing another mailman; see Figure 1):

Two mailmen and a fireman got into a fight yesterday afternoon.

- (8) Who pushed the fireman yesterday afternoon?
- (9) Who did the fireman push who yesterday afternoon?
- (10) Which mailman pushed the fireman yesterday afternoon?
- (11) Which mailman did **the fireman** push <which mailman> yesterday afternoon?

Sentence (8) is a subject-extracted *Who*-question while (9) is object-extracted. Likewise for the *Which*-questions, (10) is subject-extracted and (11), object-extracted. Results revealed chance accuracy and significantly more gazes to the incorrect referent compared to the correct referent for object-extracted *Which*-questions only (sentence (11)). More gazes to the correct referent and above-chance final comprehension was observed for each of the other three question types. Crucially, only the object-extracted *Which*-questions contained a fully realised NP (*the fireman*, bolded in 11 above) that intervenes between the displaced NP (*Which mailman*) and its gap. These patterns suggest, again, a “similarity interference” account of sentence processing deficits in agrammatic Broca's aphasia; when one NP is displaced over another and both are structured similarly, the participant with aphasia has considerable difficulty determining “who did what to whom.”¹

The current study

Our experiment further investigates the intervener account in individuals with agrammatic Broca's aphasia using a sentence–picture matching task. To this end, we embedded unaccusative verbs into two different sentence structures; consider:

- (12) The girl observed that the boy disappeared <the boy> into the trees.
- (13) The girl that observed **the boy** disappeared <the girl> into the trees.

Sentence (12) contains a complement phrase (CP; *the boy disappeared into the trees*), headed by the complementiser *that*. The embedded CP contains an unaccusative verb (*disappeared*), and thus its single argument (*the boy*) is base-generated in direct object

¹Though there is also an intervening NP (*the fireman*) in the object-extracted *Who*-question (3), the displaced constituent is simply a *Wh*-word (*who*) and thus is structurally dissimilar to the intervening NP. Hence, no interference occurs.

position and is displaced to the surface subject position of the embedded clause. Sentence (13) contains a subject-extracted relative (SR) clause, which intervenes between the displaced argument (*the girl*) of the unaccusative verb and its gap; that is, the NP *the boy* intervenes between the two elements of the filler-gap dependency chain.

The predictions that emerge from the Intervener Hypothesis are twofold. First, from the literature we predicted that, generally, individuals with agrammatic Broca's aphasia should not have difficulty comprehending sentences that contain unaccusative verbs even though they contain a filler-gap dependency. Specifically, they should exhibit above-chance comprehension of the CP constructions as in (12) because there is not an NP that intervenes between the two elements of the syntactic chain. Second and specific to the Intervener Hypothesis, we predicted that the presence of an intervening NP as in (13) should result in a comprehension deficit for LWBA who have a sentence comprehension deficit. We also included a group of age-matched control (AMC) participants to use as a comparison to our participants with aphasia, and to examine if interveners also affect final sentence comprehension in these neurologically healthy participants.

Method

Participants

Age-matched control participants—Eleven (eight females and three males) AMC participants were included in this study (mean age at time of testing: 60 years; range: 42–74 years; mean education in years: 16 years; range 12–18 years). All of the AMC participants were native English speakers with normal or corrected-to-normal visual and auditory acuity, and no reported history of active or significant alcohol and/or drug abuse, active psychiatric illness, intellectual disability, and/or other significant brain disorder or dysfunction (e.g., Alzheimer's/dementia, Parkinson's, Huntington's, Korsako?'s).

Participants with agrammatic Broca's aphasia—Seven participants with agrammatic Broca's aphasia participated in this study (mean age at time of testing: 58 years; range: 39–64 years). Participants were included if they demonstrated auditory comprehension deficits, which we defined as at- or below-chance performance on comprehension of sentences with non-canonical word order (object relatives and passives) and above-chance comprehension on canonical sentences (actives and subject relatives) as assessed by the Subject-relative, Object-relative, Active, and Passive Test of Auditory Sentence Comprehension (SOAP; Love & Oster, 2002).² All participants with agrammatic Broca's aphasia experienced a single, unilateral left-hemisphere stroke, were native English speakers with normal or corrected-to-normal visual and auditory acuity, and were right-handed before their stroke. The clinical diagnosis of agrammatic Broca's aphasia was made based on the administration of standardised language testing to determine the extent and severity of each participant's language impairment; specifically, in the areas of fluency and auditory comprehension ability. Testing included the Boston Diagnostic Aphasia Examination—Third Edition

²Example stimuli from the SOAP: *Active*: The girl chases the small boy in the green shirt. *Subject Relative*: The boy that chases the girl is wearing a green shirt. *Passive*: The boy is chased by the girl in the green shirt. *Object Relative*: The boy that the girl chases is wearing a green shirt.

(Goodglass, Kaplan, & Barresi, 2000), Western Aphasia Battery-Revised (Kertesz, 2006), and SOAP (Love & Oster, 2002). All participants were neurologically and physically stable (i.e., at least 6 months post onset), with no history of active or significant alcohol and/or drug abuse, active psychiatric illness, intellectual disability, and/or other significant brain disorder or dysfunction (e.g., Alzheimer's/dementia, Parkinson's, Huntington's, Korsako?'s). Demographic information for these participants is presented in Table 1.

All of the participants were tested at the Language and Neuroscience Group Laboratory at San Diego State University and were paid \$15 per session.

Materials and design

Ten non-alternating unaccusative verbs were selected based on their behaviour with respect to three linguistic diagnostics: occurrence in *there*-constructions, ungrammaticality with a direct object, and inability to undergo passivisation (see also Friedmann et al., 2008):

(14) There disappeared three students after class.

(15) *The teacher disappeared three students after class.

(16) *Three students were disappeared after class (by the teacher).

The unaccusative verbs were then used to create our experimental sentence items where full NPs (i.e., DET N) were used as the subject and object, and always referred to animate entities. Each set contained an introductory sentence followed by either a sentence containing an embedded complement or a SR clause, as in 17 and 18 below (see the Appendix for full set of materials used):

Introductory discourse sentence: A boy and a girl were playing in the park.

(17) The girl observed that the boy disappeared into the trees. [CP]

(18) The girl that observed the boy disappeared into the trees. [SR]

Ten sentences of each type were constructed, yielding 20 experimental sentences. Colour line drawings were created to depict all 20 experimental sentences. The reversible coloured line drawings for the CP and the SR clause constructions from each experimental set were combined so that two pictures were presented for each discourse/experimental item (see Figure 2 as an example). The 20 stimuli were randomised with the constraint that the same NP/Verb of the CP or SR constructions did not repeat within 5 items of another. Testing was completed in one session.

Procedure

The participants were presented with a discourse-sentence set as described above along with a visual stimulus (see Figure 2), one depicting the correct interpretation of the sentence, and the other a foil, reversing the two referents. The order of the pictures varied so that the position could not be used as a cue. The participants were instructed to listen carefully to each sentence and to point to the picture that best matched the sentence that they just heard. All sentences were read aloud to each participant. The participants were first familiarised

with the task with practice items prior to the presentation of the experimental stimuli. Once the participant correctly responded to both practice items, testing began.

At the beginning of each item, the two referents in each picture were identified by the experimenter. Then the participant listened to the introductory sentence followed by the experimental sentence. Each experimental sentence was read twice and could be repeated a third time upon the participant's request. All responses were marked incorrect or correct by the experimenter on a score sheet.

Analysis

Accuracy data were subjected to unequal variance t-tests to determine if comprehension of each sentence type differed from chance (50%) for each group. For each group, a paired *t*-test was performed to determine if there was a statistical difference in comprehension accuracy between the two sentence types. Probability values are presented as two-tailed.

Results

Comprehension accuracy data for both subject groups are shown in Figure 3.

For the AMC participants, comprehension of the *CP sentences* ($M = 99\%$; $SD = 3\%$, $t(10) = 54$, $p < .0001$) was above-chance. Comprehension of the *SR clause sentences* ($M = 92\%$; $SD = 13\%$, $t(10) = 11.09$, $p < .0001$) was also above-chance. For these control participants, no significant difference was found between the two sentence types, $t(10) = 1.9$, $p = 0.09$; though we note a trend in our statistical analysis, both sentences were clearly comprehended above-chance suggesting that the trend is not meaningful.

For our participants with agrammatic Broca's aphasia, mean performance on the *CP sentences* was excellent (91% ; $SD = 15\%$, $t(6) = 7.49$, $p = .0003$) and was above-chance. Comprehension of the *SR sentences* (46% ; $SD = 15\%$, $t(6) = -0.75$, $p = .48$) was not different from chance. Furthermore, for these participants with agrammatic Broca's aphasia, a significant difference was observed between the two sentence types, $t(6) = 7.47$, $p = .0003$, with performance significantly worse of the subject-extracted sentences, unlike what was observed for our control participants.

Discussion

The purpose of our study was to investigate the sentence comprehension impairment in agrammatic Broca's aphasia through the lens of the Intervener Hypothesis. We presented non-alternating unaccusative verbs in two different sentence structures—sentences with a CP and SRs. Based on the Intervener Hypothesis, we predicted that the SR condition would result in poorer comprehension than the CP condition for the participants with agrammatic Broca's aphasia. The results from the CP sentences clearly show that our participants with agrammatic Broca's aphasia do quite well (91% correct), similar to the AMC participants. Yet unlike the AMC group who performed at 92% accuracy on the SR sentences, our participants with agrammatic Broca's aphasia demonstrated poorer, and at-chance, performance (46% accuracy). This pattern of results supports our predictions: Individuals

with agrammatic Broca's aphasia only have difficulty understanding sentences containing unaccusative verbs when they are inserted into sentence constructions that contain an intervener, in the present case, inserted into subject relative constructions.

The significantly poorer performance found with the SRs cannot be attributed to the construction itself. We point out here that LWBA have been shown in the literature and here in our screening tasks to exhibit above-chance performance on SR clauses on the SOAP (see Table 1). Furthermore, there is a reasonably long history suggesting that subject-extracted, but not object-extracted sentences, are easier to understand for participants with agrammatic Broca's aphasia compared to other sentences containing filler-gap dependencies (e.g., Caramazza & Zurif, 1976; Grodzinsky, 1990; Love & Oster, 2002; among many others). Thus we propose that the Intervener Hypothesis explains this pattern and argue that when an unaccusative verb is embedded in a subject relative construction, the conditions specified by the Intervener Hypothesis are met and result in the predicted comprehension deficit.

To explain further, we repeat the relevant structure below:

(19) The girl that observed **the boy** disappeared <the girl> into the trees.

Recall that the NP (*the girl*) occupies the underlying object position for the unaccusative verb *disappeared* and is displaced to the beginning of the sentence, while crossing over the direct object NP (*the boy*) of the intervening relative clause. In line with the predictions of the Intervener Hypothesis, we suggest that the presence of the intervening NP disrupts processing the dependency chain formed when the object of the unaccusative verb was displaced to surface subject position. The result of this disruption is that the participant with agrammatic Broca's aphasia becomes confused as to "who did what to whom" due to similarity interference and thus performance suffers. As discussed in our Introduction, an intervener is a referential NP that interrupts the dependency chain composed of the displaced NP filler and its gap; if the two NPs are structured similarly (e.g., DET N), similarity interference occurs, decreasing comprehension performance. Though the details of the interference effect await further study, there is considerable evidence in the psycholinguistic literature that the effect compromises the memory system that subserves language comprehension (e.g., Gordon et al., 2006; Lewis, Vasishth, & Van Dyke, 2006; Van Dyke & McElree, 2006).

Importantly, the Intervener Hypothesis can be extended to other sentence constructions, increasing its theoretical range. As discussed in our "Introduction" section, *Wh*-questions are another test case; only object-extracted *Which*-questions yielded performance indicative of an intervener effect (see Sheppard et al., 2015). Similarly, Friedmann and Shapiro (2003) found that comprehension of topicalisation structures in Hebrew (O-S-V and O-V-S word order), those that involve displacement of an argument to the front of the sentence while also crossing over an intervening NP, are impaired in agrammatic Broca's aphasia relative to S-V-O word order sentences.

Furthermore, the following constructions ((b) versions only) also meet the structural description for interveners:

(20a) Show me the mouse that scratched the rabbit.

- (20b) Show me the mouse that **the rabbit** scratched <the mouse>.
- (21a) The dog saw that the cat licked himself.
- (21b) The dog saw that the cat licked him.

Only the object-extracted relative clause (20b), and not the subject-extracted version (20a), contains an intervening NP; as discussed in the “Introduction” section, only object-extracted relatives yield poor comprehension performance in agrammatic Broca’s aphasia (see also Friedmann & Shapiro, 2003; Garraffa & Grillo, 2008; see Friedmann & Costa, 2010; for evidence from acquisition). The sentences in (21) contain overt anaphors; personal pronouns (21b) are more difficult to understand for participants with agrammatic Broca’s aphasia relative to intact comprehension for sentences containing reflexive pronouns (21a) (Grodzinsky, Wexler, Chien, Marakovitz, & Solomon, 1993). Note that sentences with personal pronouns contain an intervening NP (boldfaced above) between the anaphor and its antecedent. We are currently conducting studies to examine the above constructions and others to determine the further generalisability of the Intervener Hypothesis. If this work uncovers a similar disruption, then the Intervener Hypothesis will extend to the processing of syntactic dependencies that are not only characterised by filler-gaps.

To conclude, we conducted an off-line experiment to investigate the comprehension of sentences containing unaccusative verbs in participants with agrammatic Broca’s aphasia who have a comprehension deficit. Our study was designed to evaluate the Intervener Hypothesis. We found above-chance comprehension of sentences containing an embedded clause with non-alternating unaccusative verbs, but comprehension suffered in subject-relative constructions that contained an intervener. We suggest, then, that one source of the comprehension deficit in agrammatic Broca’s aphasia is the presence of an intervener that is located between the two elements of a syntactic dependency chain, leading to similarity-based interference.

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APPENDIX

Stimuli used in experiment

Sentence	Type
A doctor and a nurse were attending a party.	Discourse
The doctor detected that the nurse arrived through the backdoor.	CP
The doctor that detected the nurse arrived through the backdoor.	SR
A farmer and a cowgirl were competing in a race.	Discourse
The farmer recognised that the cowgirl vanished around the corner.	CP

Sentence	Type
The farmer that recognised the cowgirl vanished around the corner.	SR
A mother and daughter were on a camping trip.	Discourse
The daughter detected that the mother arose in the middle of the night.	CP
The daughter that detected the mother arose in the middle of the night.	SR
A father and son were fishing at a lake.	Discourse
The son noticed that the father appeared from behind the bush.	CP
The son that noticed the father appeared from behind the bush.	SR
A man and a woman were vacationing at a hotel.	Discourse
The woman noticed that the man emerged from the pool.	CP
The woman that noticed the man emerged from the pool.	SR
A boy and a girl were playing in the park.	Discourse
The girl observed that the boy disappeared into the trees.	CP
The girl that observed the boy disappeared into the trees.	SR
A rollerblader and a skateboarder were practising for a competition.	Discourse
The rollerblader recognised that the skateboarder soared over the ramp.	CP
The rollerblader that recognised the skateboarder soared over the ramp.	SR
A mailman and a tourist were walking down the street.	Discourse
The tourist saw that the mailman fell in the crosswalk.	CP
The tourist that saw the mailman fell in the crosswalk.	SR
A teacher and a student were riding the bus.	Discourse
The teacher saw that the student remained on the bus.	CP
The teacher that saw the student remained on the bus.	SR
A firefighter and a policeman were attending a conference.	Discourse
The firefighter observed that the policeman departed through the lobby door.	CP
The firefighter that observed the policeman departed through the lobby door.	SR

Notes: CP = Complement phrase, SR = Subject relative.

References

- Burkhardt P, Avrutin S, Piñango M, Ruigendijk E. Slower-than-normal syntactic processing in agrammatic Broca's aphasia: Evidence from Dutch. *Journal of Neurolinguistics*. 2008; 21:120–137. doi:10.1016/j.jneuroling.2006.10.004.
- Burzio, L. Italian syntax: A government-binding approach. Reidel; Dordrecht: 1986.
- Caplan D, Waters G, DeDe G, Michaud J, Reddy A. A study of syntactic processing in aphasia I: Behavioral (psycholinguistic) aspects. *Brain and Language*. 2007; 101:103–150. doi:10.1016/j.bandl.2006.06.225. [PubMed: 16999989]
- Caramazza A, Zurif E. Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*. 1976; 3:572–582. doi:10.1016/0093-934X(76)90048-1. [PubMed: 974731]
- Chomsky, N. Lectures on government and binding. Foris; Dordrecht, the Netherlands: 1981.
- Chomsky, N. The minimalist program. Vol. 28. MIT press; Cambridge MA: 1995.
- Choy J, Thompson CK. Binding in agrammatic aphasia: Processing to comprehension. *Aphasiology*. 2010; 24:551–579. doi:10.1080/02687030802634025. [PubMed: 20535243]
- Dowty D. Thematic proto-roles and argument selection. *Language*. 1991; 67(3):547–619. doi: 10.2307/415037.

- Drai D, Grodzinsky Y. A new empirical angle on the variability debate: Quantitative neurosyntactic analyses of a large data set from Broca's Aphasia. *Brain and Language*. 2006; 96:117–128. doi: 10.1016/j.bandl.2004.10.016. [PubMed: 16115671]
- Ferrill M, Love T, Walenski M, Shapiro LP. The time-course of lexical activation during sentence comprehension in aphasia. *American Journal of Speech-Language Pathology*. 2012; 21:179–189. doi:10.1044/1058-0360(2012/11-0109).
- Friedmann, N. Agrammatic aphasia and the psychological reality of the syntactic tree. In: Hatav, G., editor. *Theoretical Hebrew linguistics*. Magnes; Jerusalem, Israel: 2008. p. 339-368.
- Friedmann N, Costa J. The child heard a coordinated sentence and wondered: On children's difficulty in understanding coordination and relative clauses with crossing dependencies. *Lingua*. 2010; 120:1502–1515. doi:10.1016/j.lingua.2009.10.006.
- Friedmann, N.; Gvion, A. Intervention and Locality in agrammatic aphasia. In: Bianchi, V.; Chesi, C., editors. *Enjoy Linguistics! Papers offered to Luigi Rizzi on the occasion of his 60th birthday*. CISCL Press; Siena, Italy: 2012.
- Friedmann N, Shapiro LP. Agrammatic comprehension of simple active sentences with moved constituents: Hebrew OSV and OVS structures. *Journal of Speech, Language, and Hearing Research*. 2003; 46:288–297. doi:10.1044/1092-4388(2003/023).
- Friedmann N, Taranto G, Shapiro L, Swinney D. The leaf fell (the leaf): The online processing of unaccusatives. *Linguistic Inquiry*. 2008; 39:355–377. doi:10.1162/ling.2008.39.3.355. [PubMed: 22822348]
- Garraffa M, Grillo N. Canonicity effects as a grammatical phenomenon. *Journal of Neurolinguistics*. 2008; 21:177–197. doi:10.1016/j.jneuroling.2007.09.001.
- Goodglass, H.; Kaplan, E.; Barresi, B. *Boston diagnostic aphasia examination*. 3rd. Taylor & Francis; Philadelphia: 2000.
- Gordon PC, Hendrick R, Johnson M. Effects of noun phrase type on sentence complexity. *Journal of Memory and Language*. 2004; 51:97–114. doi:10.1016/j.jml.2004.02.003.
- Gordon PC, Hendrick R, Johnson M, Lee Y. Similarity-based interference during language comprehension: Evidence from eye tracking during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2006; 32:1304.
- Grillo, N. Minimality effects in agrammatic comprehension. In: Blaho, S.; Vicente, L.; Schoorlemmer, E., editors. *Proceedings of ConSOLE XIII*. Leiden University; Leiden, the Netherlands: 2005. p. 106-120.
- Grillo N. Generalized Minimality: Feature impoverishment and comprehension deficits in agrammatism. *Lingua*. 2009; 119:1426–1443. doi:10.1016/j.lingua.2008.04.003.
- Grodzinsky, Y. *Theoretical perspectives on language deficits*. MIT Press; Cambridge, Mass: 1990.
- Grodzinsky Y, Wexler K, Chien Y-C, Marakovitz S, Solomon J. The breakdown of binding relations. *Brain and Language*. 1993; 45:396–422. doi:10.1006/brln.1993.1052. [PubMed: 8269332]
- Hovav MR, Levin B. An event structure account of English resultatives. *Language*. 2001; 77:766–797. Retrieved from <http://www.jstor.org/stable/3086847>.
- Kertesz, A. *Western aphasia battery*. PsychCorp; San Antonio: 2006.
- Koring L, Mak P, Reuland E. The time course of argument re-activation revealed: Using the visual world paradigm. *Cognition*. 2012; 123:361–379. doi:10.1016/j.cognition.2012.02.011. [PubMed: 22475295]
- Lee M, Thompson C. Agrammatic aphasic production and comprehension of unaccusative verbs in sentence contexts. *Journal of Neurolinguistics*. 2004; 17:315–330. doi:10.1016/S0911-6044(03)00062-9. [PubMed: 21311719]
- Lewis RL, Vasishth S, Van Dyke JA. Computational principles of working memory in sentence comprehension. *Trends in Cognitive Science*. 2006; 10:447–454. doi:10.1016/j.tics.2006.08.007.
- Love T, Oster E. On the categorization of aphasic typologies: The SOAP (a test of syntactic complexity). *Journal of Psycholinguistic Research*. 2002; 31:503–529. doi:10.1023/A:1021208903394. [PubMed: 12528429]
- Love T, Swinney D, Walenski M, Zurif E. How left inferior frontal cortex participates in syntactic processing: Evidence from aphasia. *Brain and Language*. 2008; 107:203–219. doi:10.1016/j.bandl.2007.11.004. [PubMed: 18158179]

- McAlister T, Bachrach A, Waters G, Michaud J, Caplan D. Production and comprehension of unaccusatives in aphasia. *Aphasiology*. 2009; 23:989–1004. doi:10.1080/02687030802669518.
- Perlmutter, DM. Impersonal passives and the Unaccusative Hypothesis; Proceedings of the 4th Annual Meeting of the Berkeley Linguistics Society; Berkeley: University of California, Berkeley Linguistics Society. 1978. p. 157-189.
- Perlmutter, DM.; Postal, PM. The 1-Advancement Exclusiveness Law. In: Perlmutter, DM.; Rosen, C., editors. *Studies in Relational Grammar 2*. University of Chicago Press; Chicago: 1984. p. 81-126.
- Piñango, MM. Canonicity in Broca's sentence comprehension: The case of psychological verbs. In: Grodzinsky, Y.; Shapiro, L.; Swinney, D., editors. *Language and the brain: Representation and processing*. Academic Press; San Diego/London: 2000. p. 327-350.
- Rizzi, L. Locality and left periphery. In: Belletti, A., editor. *Structures and Beyond: The cartography of syntactic structures*. Vol. 3. Oxford University Press; New York, NY: 2004.
- Sheppard SM, Walenski M, Love T, Shapiro LP. The auditory comprehension of Wh-Questions in aphasia: Support for the intervener hypothesis. *Journal of Speech, Language, and Hearing Research*. 2015; 58:781–797. doi:10.1044/2015_JSLHR-L-14-0099.
- Van Dyke JA, McElree B. Retrieval interference in sentence comprehension. *Journal of Memory and Language*. 2006; 55:157–166. doi:10.1016/j.jml.2006.03.007. [PubMed: 18209744]
- van Valin RD. Semantic parameters of split intransitivity. *Language*. 1990; 66:221–260. doi: 10.2307/414886.

Figure 1.
Example of three-figure image used in Sheppard et al's. (2015) eye tracking-while-listening study.

Figure 2.

Example used in sentence–picture matching task for the verb “disappeared”.

Discourse: A boy and a girl were playing in the park. COMPLEMENT PHRASE: The girl

observed that the boy disappeared into the trees. SUBJECT RELATIVE: The girl that

observed the boy disappeared into the trees.

Figure 3.

Percentage correct for comprehension of each sentence type for age-matched control participants ($n = 11$) and participants with agrammatic Broca's aphasia ($n = 7$).

Table 1

Demographic information for individuals with agrammatic Broca's aphasia.

Participant	Gender	Years post-stroke	Lesion location*	Age at testing	Education in years	BDAE [†] severity level	SOAP [‡] canonical (%)	SOAP [§] non-canonical (%)
LHD009	M	13	LH lesion involving inferior frontal gyrus (BA44, 45)	53	17	3	75	55
LHD101	M	7	LH lesion involving posterior inferior frontal gyrus (BA44) with posterior extension	64	20	2	95	35
LHD130	M	5	L IPL with posterior extension sparing STG	61	16	4	95	65
LHD132	M	9	LH lesion involving inferior frontal regions with extension to the anterior two thirds of STG & MTG	50	16	4	85	55
LHD140	F	13	L MCA infarct secondary to occlusion of L proximal CA	39	16	2	80	30
LHD142	M	3	L MCA infarct	75	8	4	100	65
LHD159	F	3	L MCA infarct	61	14	3	100	70
		M = 8		M = 58	M = 15	M = 3	M = 90%	M = 54%
		SD = 4		SD = 11	SD = 4	SD = 1	SD = 10	SD = 15

* L = left; LH = left hemisphere; BA = Brodmann area; IPL = inferior parietal lobule; STG = superior temporal gyrus; MTG = middle temporal gyrus; MCA = middle cerebral artery; CA = cerebral artery.

[†]BDAE = Boston Diagnostic Aphasia Examination (0 = no usable speech or auditory comprehension, 5 = minimal discernable speech handicap).

[‡]SOAP Canonical = Average percent correct of active and subject relative items on Subject-relative, Object-relative, Active, and Passive Test of Auditory Sentence Comprehension (SOAP) Test of Auditory Sentence Comprehension.

[§]SOAP Non-Canonical = Average percent correct of passive and object relative items on SOAP Test of Auditory Sentence Comprehension.