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What Goes Wrong during Passive Sentence Production in Agrammatic Aphasia: An Eyetracking Study

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Abstract

Background—Production of passive sentences is often impaired in agrammatic aphasia and has been attributed both to an underlying structural impairment (e.g., Schwartz, Saffran, Fink, Myers, & Martin, 1994) and to a morphological deficit (e.g., Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003). However, the nature of the deficit in passive sentence production is not clear due to methodological issues present in previous studies.

Aims—This study examined active and passive sentence production in nine agrammatic aphasic speakers under conditions of structural priming using eyetracking to test whether structural impairments occur independently of morphological impairments and whether the underlying nature of error types is reflected in on-line measures, i.e., eye movements and speech onset latencies.

Methods & Procedures—Nine participants viewed and listened to a prime sentence in either active or passive voice, and then repeated it aloud. Next, a target picture appeared on the computer monitor and participants were instructed to describe it using the primed sentence structure.

Outcomes & Results—Participants made substantial errors in sentence structure, i.e., passives with role reversals (RRs) and actives-for-passives, but few errors in passive morphology. Longer gaze durations to the first-produced noun for passives with RRs as compared to correct passives were found before and during speech. For actives-for-passives, however, this pattern was found during speech, but not before speech.

Conclusions—The deficit in passive sentence production does not solely arise from a morphological deficit, rather it stems, at least in part, from a structural level impairment. The underlying nature of passives with RRs is qualitatively different from that of actives-for-passives, which cannot be clearly differentiated with off-line testing methodology.

Keywords

Aphasia; Agrammatism; Passive sentence production; Passive morphology; Thematic role assignment; Eyetracking

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Individuals with agrammatic aphasia often have difficulty producing syntactically complex sentences such as passives. Some studies have attributed this difficulty to a structural deficit (e.g., Schwartz et al., 1994), whereas others have attributed it to a morphological impairment (e.g., Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003). However, the source of the passive sentence production deficit remains unclear due to methodological issues present in previous studies. Understanding the nature of this production deficit is important for the assessment and treatment of language disorder in aphasia.

A handful of studies suggest that the inability to produce appropriate passive morphology underlies the impairment in passive sentence production (i.e., auxiliary, *-ed*, preposition *by*) (e.g., Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003; Menn, Reilly, Hayashi, Kamio, Fujita, & Sasanuma, 1998; Weinrich, Boser, McCall, & Bishop, 2001). For example, Caplan and Hanna (1998) examined the relationship between thematic roles and grammatical morphology using actives and passives in 14 Broca's aphasic speakers. They used a picture description task in which participants heard verbs, saw pictures of a simple transitive event, and described the pictures using a single sentence. Participants were asked to start a sentence with one of the two event participants, either the Agent or Theme, marked with a dot to obligate production of either an active or passive sentence, respectively. They found that production of thematic roles was easier in active sentences than in passive sentences, and grammatical morphemes (i.e., auxiliary, and *by*) related to thematic role assignment were more impaired than those not related to thematic role assignment (e.g., noun determiners). For example, a response *the bag give the clerk* for the target *the bag was given by the clerk* does not contain any passive morphology. In this study, at least two out of three passive morphological indicators were required in order for a response to be identified as a passive sentence. Despite correct word order in the example above, the thematic role for *the clerk* was scored as incorrect mainly because the agent was not properly produced with passive morphology. These results suggested that impaired grammatical morphology, which conveys thematic roles, rather than the impaired thematic role assignment itself, is associated with difficulty producing thematic roles in non-canonical sentences. This finding was replicated in the study by Faroqi-Shah and Thompson (2003): 50% of the total errors produced for passive targets contained role reversals (RRs), and 63% of these errors co-occurred with errors in auxiliaries and/or prepositions, suggesting that impaired grammatical morphology, rather than impaired thematic role assignment, resulted in difficulty producing passive sentences.

Other studies, however, suggest that thematic role assignment, irrespective of passive morphology, is impaired: this has been demonstrated in several languages, including English (e.g., Bastiaanse & Edwards, 2004; Bastiaanse, Edwards, Maas, & Rispens, 2003; Caramazza & Berndt, 1985; Mitchum, Greenwald, & Berndt, 1997), Dutch (e.g., Bastiaanse & Edwards, 2004), and Spanish (e.g., Benedet, Christiansen, & Goodglass, 1998). For example, Bastiaanse and Edwards (2004) examined the production of non-canonical sentences using a sentence anagram test in which participants arranged word cards (e.g., *the child*/ *is washed by*/ *the mother*) in the order corresponding to a picture presented. They found that the majority of errors for passive targets were RRs, suggesting that aphasic patients exhibited difficulty mapping thematic roles onto grammatical roles even when passive morphology did not play a role in building passive structures. Impairments in thematic role assignment also have been found in production of simple canonical sentences, i.e., active transitives and locatives (e.g., Saffran, Schwartz, & Marin, 1980).

Close examination of methodologies used in the aformentioned studies, however, raises questions regarding the conclusions drawn from them. Studies pointing to impaired passive morphology (e.g., Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003) explicitly provided the first noun of a sentence to start with. Notably, by using this experimental paradigm in which only two event participants are pictured, RRs are unlikely to be produced. As previously suggested, if RRs in passives are by-products of impaired passive morphology, the number of RRs would drastically decrease by using an experimental paradigm that facilitates production of passive morphology. Thus, further research examining passive sentence production is needed. The current study used a methodology that cues passive morphology, but does not provide explicit cues for the first noun in a sentence (i.e., a structural priming paradigm; Bock, 1986), in order to examine whether or not impaired thematic role assignment results from impaired passive morphology. This method is appealing for studying agrammatic aphasia because agrammatic speakers show ability to produce sentences under structural priming conditions that they cannot otherwise produce (Hartsuiker & Kolk, 1998; Marin & Schwartz, 1998; Saffran & Martin, 1997). Further, structural priming has been shown to be particularly effective for eliciting grammatical morphology (i.e., passive morphology and verb inflection) in agrammatic speakers (Hartsuiker & Kolk, 1998; Marin & Schwartz, 1998).

Error analysis of passive sentence production in agrammatic aphasia also has differed across studies because thematic role assignment, in particular, is extremely difficult to score. That is, some form of passive morphology needs to be present in order to differentiate one thematic role from the other. Due to the nature of agrammatism, passive sentence productions often do not have complete passive morphology, leading to difficulty identifying thematic roles. As a result, the use of the term RR has not been uniform within and across studies.

In most studies, RR has denoted either (1) the opposite agent-theme relation in a passive voice (*the boxer is punched by the bartender* for *the bartender is punched by the boxer*) (e.g., Bastiaanse et al., 2003) or (2) the active voice produced for the passive voice (*the bartender is punching the boxer* for *the bartender is punched by the boxer*) (e.g., Faroqi-Shah & Thompson, 2003). Due to the clear indication of passive morphology, the first example would be, without any doubt, a RR, indicating the pure inability to map thematic roles onto grammatical roles. This can be determined with certainty when specific experimental paradigms are used (e.g., the anagram test). However, the second example is not as straightforward as the first one as it lacks morphological indicators of thematic roles. It can be considered an attempt to produce either a passive sentence with a failure of passive morphology production (e.g., Caplan & Hanna, 1998) or an active sentence with a RR, but not both. It is most likely to be the former because this pattern was found in studies that provided the first noun to start with, resulting in relatively preserved thematic role assignment. In this regard, the second example should not be scored as a passive with a RR. In addition, one more example (e.g., *the boxer is punching the bartender* for *the bartender is punched by the boxer*) has also been scored as a RR in some studies (e.g., Faroqi-Shah & Thompson, 2003), but not in others (e.g., Benedet et al., 1998; Caplan & Hanna, 1998). This example describes the target picture using the non-target active voice with appropriate thematic role assignment, indicating that this does not contain a RR. This may be an attempt to use a default voice that is more accessible to agrammatic speakers (Benedet et al., 1998; Caplan & Hanna, 1998). Such a response can be considered a passive with a RR only if it is considered an attempt to produce a passive sentence with impaired passive morphology as well as thematic role assignment. Taken together, three types of errors reviewed above have often been analyzed as RRs, nevertheless, they may result from very different underlying impairments.

Off-line production data by agrammatic speakers, as reviewed above, are often too vague and limited to provide the speakers' intent. On-line measures, e.g., eye movements in conjunction with speech onset latencies, have been informative for examining the underlying processes of sentence production in real-time (Griffin 2004; Meyer, 2004).

Before speech, speakers comprehend an event, generate a corresponding message, and identify event participants with respect to ‘who is doing what to whom’ (Griffin & Bock, 2000; van der Meulen, 2003). According to models of sentence production (e.g., Bock & Levelt, 1994), the choice of passive voice is decided upon by the availability of a noun lemma conveying the theme of an action (Bock, Loebell, & Morey, 1992). Thus, any structural differences between correct and incorrect passives should be noticeable in the ‘before speech’ region.

During speech, sentences are formulated and executed. Eye movements during speech are associated with ordering and encoding sentential constituents (Griffin & Bock, 2000). Prior to referring to event participants, speakers gaze at each one in the order of production for name selection and phonological encoding (Griffin, 2001; Meyer, Sleiderink, & Levelt, 1998). Before articulating each name, speakers tend to shift their gaze to the next object to name (Meyer et al., 1998; Meyer & van der Meulen, 2000). Also, speakers’ difficulty encoding lexical items are reflected in longer gaze durations (Griffin, 2001; Meyer et al., 1998; Meyer, 2004). Factors affecting this encoding difficulty include low frequency of occurrence (Griffin, 2001; Meyer et al., 1989) and word length (Zelinsky & Murphy, 2000).

In aphasia research eye movements have been used mostly in comprehension, but not production, studies (e.g., Dickey, Choy, & Thompson, 2007; Dickey & Thompson, 2009). To our knowledge, there is one published study that examined sentence production in agrammatic speakers using eye movements (Thompson, Dickey, Cho, Lee, & Griffin, 2007). In this study, production of sentences with two- and three-argument verbs were examined in 9 agrammatic and 12 healthy control speakers using a picture description task. The main finding of the study was that the gaze patterns associated with correct responses (for two-argument verbs) produced by the agrammatic speakers were incremental to their production as they were for the control speakers, but not those associated with incorrect responses. As a pioneering study, this study provided evidence of normal incremental gaze patterns to speech in agrammatic speakers.

The purpose of this study was to examine passive sentence production in agrammatic aphasia under conditions of structural priming using eyetracking. First, we examined whether impairments in passive sentence structure can occur independently of impairments in passive morphology. Second, we examined whether on-line measures, eye movements as well as speech onset latencies, reflect the underlying nature of different types of passive sentence production errors that have often been unclear in studies examining off-line sentence production.

Method

Participants

Nine individuals with agrammatic Broca’s aphasia (eight males; mean age: 53 years, age range: 38–66) participated in the study: P1-P9. All were native speakers of English except one participant who was premorbidly a Spanish-English bilingual. Though his first language was Spanish, English had been his primary language since the age of four and it was preserved to a greater degree than Spanish at post-stroke. All participants suffered a thrombo-embolic stroke in the left hemisphere and did not have any history of neurological and speech-language disorders prior to their stroke. All participants were right handed, with exception of on one, well-educated (mean = 17 years, range = 12 – 19) and demonstrated visual and hearing acuity within normal limits.

Aphasia was assessed using the Western Aphasia Battery (WAB; Kertesz, 1982). Aphasia quotients (AQs) derived from the WAB ranged from 71.2 to 82.4 (mean = 76.89). Auditory comprehension, while mildly impaired, was superior to verbal expressive ability. In addition, data from the Northwestern Assessment of Verbs and Sentences (NAVS; Thompson, experimental version) indicated that passive sentences were more impaired than active sentences in both comprehension and production. Data from the Northwestern Assessment of Verb Inflection (NAVI; Thompson, experimental version) indicated that the *–ed* form was impaired whereas the *-ing* form was relatively preserved, except for P7 and P9. P1 could not be tested with the NAVI due to fatigue and limited time. Both demographic and language testing data are provided in Table 1.

Material

Forty prime sentences (20 actives, 20 passives) were paired with 40 pictures of target transitive events, which elicited target sentences. All sentences were semantically reversible and included two animate nouns (e.g., *boy*, *girl*) and a transitive verb (e.g., *chase*). Regular verbs were used in order to avoid difficulty in verb conjugation except one active prime (i.e., bite). In order to equate the number of words in the verb phrase of target sentences, present progressive tense was used in the active primes, and simple present tense was used in the passive primes. For the primes, the nouns were matched for the $\log_{10}$ lemma frequency per million (CELEX; Baayen, Piepenbrock, & van Rijn, 1993) between prime types (mean = 1.64 vs. 1.52 for the active and passive primes) (two-way ANOVA, F (1, 76) = .629, p = .430), and between the event participants (mean = 1.55 versus 1.61 for the agents and themes) (F (1, 76) = .147, p = .702). The verbs in the active and passive condition were also matched for the frequency in the same manner (mean = 1.5 vs. 1.64) (t(38) = .706, p = .484). For the targets, the nouns were equated for the frequency between prime types (mean = 2.02 versus 2.11 for the targets paired with the active primes and the passive primes) (two-way ANOVA, F (1, 76) = .167, p = .684) and between event participants (mean = 2.09 versus 2.04 for the agents and themes) (F (1, 76) = .056, p = .814), and the verbs were repeated from the primes. The nouns and verbs used in the primes and targets were also controlled for syllable length. For visual presentation, the primes were typed in 44 point font, and for auditory presentation they were digitally recorded using SoundEdit 16 by a female native speaker of English at a normal rate. Lists of prime sentences and target events are provided in Appendices A and B, respectively.

Target pictures, 40 black and white line drawings, were prepared on 8.5” × 11” cards. The pictures depicted a transitive action with two event participants (i.e., the agent and the theme) without any additional elements. The location of these participants was pseudorandomized by placing them next to each other, or above and below each other. All the picture stimuli were normed by nine native speakers of English, and elicited the target sentences at the rate of 97 percent.

Both visual and auditory stimuli were entered into Superlab 2.0 (Cedrus, Phoenix, AZ). The visual stimuli were presented on a 15-inch Macintosh monitor and the audio stimuli were presented through a loud speaker attached to the Macintosh. The prime sentences and the target pictures were displayed on the monitor until the participants clicked on the mouse. Between the primes and the targets, a blank white screen appeared for 300 milliseconds, followed by a black fixation cross for 2000 milliseconds. Then, the target pictures were presented simultaneously with the beep. Sample stimuli for both active and passive conditions are provided in Figure 1.

Procedures

Participants were seated in front of the stimulus presentation computer monitor in a dimly lit room. The monitor was located approximately 24 inches from the participants’ eyes. A Canon remote camera, situated below the monitor, was used to monitor and record eye movements. In order to minimize head movements, participants rested their chin on a UHCO chin rest. The Applied Science Laboratories (ASL) 504 remote eye tracker, linked to a Dell computer, was calibrated to each participant's eyes at the beginning of the experiment and additional calibrations took place following four practice items and after every ten trials thereafter. The remote camera sampled the position and direction of the participants' fixation once every 16 ms. Speech was recorded through a microphone using Praat 5.0.

The experiment consisted of two blocks, each containing 20 trials. The order of these blocks was pseudorandomized across participants. On experimental trials, participants viewed and listened to a prime sentence, and then were instructed to repeat it aloud. Next, a target picture appeared on the computer monitor and participants were instructed to describe it using the primed sentence structure. This explicit, rather than implicit, instruction for reusing the sentence structure was adopted because it elicited numerically a higher number of targeted structures in Hartsuiker and Kolk (1998). In order to avoid any delays in word retrieval, participants were familiarized with the nouns and verbs used in the pictures prior to the experiment.

Data Analysis

Sound files for each participant were transcribed and scored. For each trial, all responses produced to describe target pictures, including fillers (e.g., uh, um) and self corrections, were transcribed. When there was more than one attempt on a single trial, only the first attempt was scored and analyzed in order to avoid difficulty aligning eye movements with speech data. In order to be considered as an attempt, the utterance had to at least contain a subject and a verb.

Responses were scored for three elements: thematic role assignment, phrase structure, and grammatical morphology. Correct responses included active and passive responses produced in corresponding prime conditions. Responses were scored as *actives* if the phrase structure followed an NP AUX V NP order, and the verb form was present progressive verb (i.e., auxiliary *is* and *-ing*). Responses were scored as *passives* if the structure followed an NP AUX V NP order, and all of the passive morphology (i.e., auxiliary *is*, *-ed*, and preposition *by)* was present. In addition, the following substitutions were accepted: a correct target noun in any form (e.g. *a boy* and *the boy*); a noun with an additional modifier (e.g. *a tall girl*); a semantically similar and gender appropriate noun (e.g. *lady* for *woman* and *guy* for *man*); and a semantically similar verb with the same argument structure as the target verb (e.g. *push* for *shove*). Repetition of one of the two nouns from the paired prime was allowed only if the noun was semantically similar and gender appropriate to the target noun (e.g., *the sister is tickling the boy* for *the girl is tickling the boy* when the prime was *the brother is biting the sister*). Phonemic paraphasias were also accepted when 50% or more phonemes of a target word were produced.

Incorrect responses included the following. Responses were scored as *grammatical morphology errors* if thematic roles were appropriately assigned and the responses omitted or substituted any single morphological indicator in each condition. Responses were scored as *RRs* if two event participants indicated by grammatical morphology were misplaced in the target voice. Responses were scored as *sentence type errors* if actives were produced in the passive condition (actives-for-passives), or vice versa (passives-for-actives). Responses were scored as *incorrect lexical items* if they contained words not related to target words: nouns and verbs that were semantically different from targets; verbs that were semantically similar, but with different verb argument structures from target verbs; a gender neutral noun repeated from the paired prime; and both nouns directly repeated from the paired prime. Responses that did not satisfy the criteria described above were scored as *others* (e.g., incomplete responses containing a subject and an auxiliary only). For these responses, the voice was determined based on their second or third attempts that contained more sentential elements than the first attempt. Examples of incorrect responses are provided in Appendix C.

Speech onset latency was measured for each content word, i.e., the first noun (N1), the main verb (V), and the second noun (N2) using Praat 5.0. Time from onsets of picture stimuli to the onset of each content word was measured. When there were self-corrections within a word, the onset was measured from the beginning of the first attempted morpheme that was phonetically similar to a target morpheme.

Eye movement analysis was conducted based on areas of interest (AOI). AOIs were defined by the location of the event participants of interest in the picture stimuli. Pictures with similar spatial arrays were grouped together using three spatial templates. In each template, there were two squares which covered each event participant in the picture with approximately two degrees of visual angle. Fixations which fell inside these squares were counted as fixations to the event participant covered by the square. In order to qualify as a fixation, a speaker had to fixate on the same position for six consecutive samples or 100 milliseconds. Temporally adjacent fixations in the same AOI (i.e., on the same event participant) were summed to determine *gaze durations*. Once gaze onsets were aligned with the onset latencies of N1, V, and N2, gaze duration to each event participant, the total duration of time spent gazing at each one, was calculated within a given speech region, i.e., the PRE N1 (before speech onset), N1-V and V-N2 (during speech) regions.

Results

A total of 352 responses (178 in the passive condition) were analyzed out of 360 trials (40 sentences × 9 participants). Eight responses were excluded due to experimental error. Table 2 shows the mean percentage distribution in the active and passive condition. As expected, the mean percent correct in the passive condition (mean = 39.33%, SD = 25.97) was significantly lower than that for the active condition (mean = 67.4%, SD = 23.05) ($t(8) = 5.019$, $p < .01$).

Table 3 provides the distribution of error types elicited in both active and passive conditions. A 2 (sentence type) x 5 (error type) ANOVA revealed main effects of sentence type (F (1, 8) = 28.766, $p < .01$) and error type (F (1, 8) = 7.879, $p < .05$): the passive condition elicited a higher number of errors compared to the active condition, and the number of RR errors was significantly higher than that of grammatical morphology errors ($p < .01$) and others ($p < .05$). In addition, the interaction between sentence type and error type almost reached significance (F (1, 8) = 5.313, $p = .050$). Post hoc tests revealed that RR errors were elicited significantly more in the passive compared to active conditions, ($t(8) = 2.920$, $p < .05$), but the rest of error types did not show any differences between conditions.

On-line data analysis was further conducted for correct passive responses and selected error types in the passive condition, i.e., RRs and actives-for-passives, in order to examine any differences between the two error types. A one way ANOVA indicated a main effect of speech onset latency (F (2, 23) = 4.420, $p < .05$). Post-hoc analysis using Wilcoxon Signed Ranks Test revealed that the participants spent a significantly longer time before producing passives with RRs (Mean = 6907 ms, SD = 2695) as compared to actives-for-passives (Mean = 4219 ms, SD = 943) ($Z = -2.521$, $p < .05$). In addition, producing actives-for-passives took a significantly shorter amount of time as compared to correct passives (Mean = 5773 ms, SD = 1393) ($Z = -2.521$, $p < .05$).

Figures 2 (a) and (b) show the mean gaze duration to N1 in incorrect (RRs and actives-for-passives, respectively) passives compared to correct passives by speech region. When producing passives with RRs (e.g., *the aunt is served by the uncle* for *the uncle is served by the aunt*) (see Figure 2a), the participants spent a longer time looking at N1 (e.g., *the aunt*) as compared to producing N1 (e.g., *the uncle*) in correct passives both in the PRE N1 (mean = 2452 ms, SD = 1069 versus mean = 1327 ms, SD = 488) ($t(8) = 5.057$, $p < .01$) and N1-V regions (mean = 1215 ms, SD = 895 versus mean = 381 ms, SD = 227) ($t(8) = 3.078$, $p < .05$). For actives-for-passives (e.g., *the dog is licking the cat* for *the cat is licked by the dog*) (see Figure 2b), however, the difference between correct passives and actives-for-passives was found in the N1-V region ($Z = -2.380$, $p < .05$, Wilcoxon Signed Ranks Test), but not in the PRE N1 region ($Z = -1.400$, $p > .05$, Wilcoxon Signed Ranks Test). That is, in the N1-V region the participants gazed longer at N1 (e.g., *the dog*) of actives-for-passives (mean = 991 ms, SD = 391) compared to that (e.g., *the cat*) of correct passives (mean = 381 ms, SD = 227). Mean gaze durations to N1 by participants are summarized in Table 4.

Discussion

One of the main findings from this study is that impairments in passive sentence structure can occur regardless of impairments in passive morphology. The off-line data showed that under conditions of structural priming the agrammatic speakers were able to produce passive sentences with relatively preserved passive morphology, but with substantial RR errors (8% and 38% of the total percentage of errors in the passive condition, respectively). If difficulty producing passives arises mainly from morphological impairments, we would not have found RR errors in this study. This indicates that impaired thematic role assignments are not a by-product of the inability to access and/or produce passive morphology, inconsistent with the conclusions drawn from the previous studies (Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003).

This inconsistency may be attributed to a methodological issue. Studies supporting impaired grammatical morphology unanimously used a task that cued the first noun to produce, whereas the current study as well as studies supporting impaired thematic role assignment used a task that did not explicitly cue the first noun. As pointed out earlier, the former compared to the latter is more likely to reduce agrammatic speakers' burden of selecting the theme as a sentential subject in passive sentences, thereby lowering the chance of incorrect thematic role assignment and highlighting the impaired morphology. Taken together with the current findings, it seems fair to state that complex sentence production deficits in agrammatic aphasia arise, to some degree, from both structural and morphological levels. Depending on which level is facilitated by a particular task, however, impairments at one level may appear to be more prominent than the other. By using a structural priming paradigm, at least, morphological impairments were separated from structural impairments in the current study.

Production of verb morphology associated with active and passive sentences was relatively intact, in keeping with findings derived from other studies of agrammatic speakers (Hartsuiker & Kolk, 1999; Marin & Schwartz, 1998). However, this is inconsistent with studies of neurologically healthy speakers in that closed-class items such as prepositions, complementizers, and verb inflections are not sensitive to structural priming (e.g., Bock, 1989, Ferreira, 2003; Pickering & Branigan, 1998). That is, when particular closed-class items are provided in prime sentences, healthy speakers do not necessarily stick to them in order to produce target sentences. The different pattern seen between agrammatic and healthy speakers may be explained by the *inverse-preference effect*: "*learning ought to be sensitive to the learner's current state of knowledge, such that when something is poorly known, it should be subject to greater learning*" (Ferreira & Bock, 2006). Grammatical morphology priming in agrammatic speakers may result from their particular difficulty with closed-class items, whereas no necessity of priming for healthy speakers may result from their full access to grammatical morphology. In line with greater learning for poorly known material, there were eleven cases where passives were produced in the active condition (i.e., passives-for-actives) (see Table 3). These passives were the correct descriptions of target pictures using the non-target voice. This overly primed passive sentence production can also be attributed to the agrammatic speakers' greater difficulty producing passives compared to actives. It seems apparent that priming occurs at the morphological level in agrammatic speakers, but it is not clear whether this priming extends to thematic role assignments, as reported in healthy speakers (e.g., Chang, Bock, & Goldberg, 2003; Hare & Goldberg, 2000). Given that 39% of responses in the passive condition were correct and 38% of the total errors in the passive condition were RRs, which shows some evidence of access to passive lemmas (see further discussion below), it may be that thematic roles were affected by structural priming. However, the precise nature of structural priming in agrammatic aphasia is not completely understood and further investigation is warranted.

Another main finding of the study was that the nature of the two most frequently, but inconsistently, documented errors (i.e., RRs and actives-for-passives), revealed by the on-line measures, was qualitatively different. Longer onset latencies of RRs compared to actives-for-passives show that the planning processes associated with these two error types were different. Further differences were revealed by the gaze duration data. The gaze duration data showed that both error types compared to correct passives were associated with longer gaze durations, indicating production difficulty (e.g., Meyer, 2004). This difficulty, however, appeared at different speech regions for the two error types. During speech, longer gaze durations to N1 (the N1-V region) showed up for both error types as compared to when correct passives were produced. Before speech (the PRE N1 region), however, this pattern was noted for RRs, but not for actives-for-passives. That is, the difference between the two error types showed up in the pre-N1 region.

As stated in the introduction, gaze duration data before speech provide essential information regarding the choice of sentence structure (i.e., active versus passive). The longer gaze durations before producing RRs as compared to correct passives suggest that the agrammatic speakers were aware of the conflict between the thematic role primed (Theme) and the thematic role they were going to assign to N1 (Agent). This awareness was also reflected in longer speech onset latencies for RRs as compared to those for correct passives. Anecdotally, some participants expressed their awareness in production. Shorter mean onset latency of actives-for-passives compared to that of correct passives suggest that the agrammatic speakers did not spend the time required to prepare production of passive sentences before speech, possibly resulting in the most accessible sentence structure, i.e., actives. The longer gaze durations upon producing actives-for-passives as compared to correct passives indicate that the speakers may have realized their incorrect production upon producing N1.

These on-line data have further implications on the source of sentence production deficits in agrammatic aphasia. RRs, as defined in this study, may result from the ability to access passive lemmas, but failure in mapping thematic roles (e.g., theme) onto grammatical roles (e.g., nominative) and/or sentential positions (e.g., subject). One may argue that RRs were formulated by a simple repetition of passive morphology from primes and use of the default active sentence structure without activating passive lemmas. Without any access to passive lemmas, however, it is challenging to explain the evident difficulty, revealed by the on-line measures, before and during speech. The lengthy gaze as well as long speech onset latency must have resulted from mapping difficulty, i.e., conflicts between the thematic roles (agent versus theme), rather than other factors such as word frequency and length that were controlled for the present study. Support for impairments at the post lemma level come from previous studies suggesting mapping difficulty and thus faulty sentence building processes (e.g., Lee & Thompson, 2004; Saffran et al., 1980; Thompson & Lee, 2009). Unlike RRs, actives-for-passives may result from the inability to access and/or activate passive lemmas, resulting in the use of the default active voice that requires a lower threshold compared to the passive voice (Menn et al., 1989).

The current findings make several important contributions to our understanding of sentence production deficits in agrammatism. First, difficulty producing passives in agrammatic aphasia does not solely result from impaired passive morphology, rather it stems, at least in part, from impaired passive sentence structure. The off-line data (i.e., sentence production data) bring attention to the importance of the methodology used to evaluate aphasic sentence production, in that it can affect the results and conclusions derived. Second, the on-line data (i.e., speech onset latencies and eye movements) suggest that two of the most frequently, but not consistently, documented errors of passive sentence structure, i.e., RRs and actives-for-passives, arise from qualitatively different underlying processes of sentence planning and formulation.

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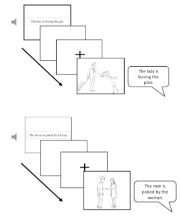

Figure 1.
Sample stimuli for the active (top) and passive (bottom) conditions

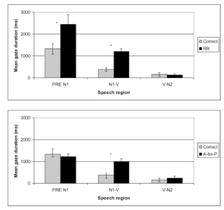

Figure 2.

Mean gaze duration to the first noun produced by speech region in correct and incorrect passives. Error bars represent standard errors.

(a) Correct passives (correct) (lined) vs. Passives with RRs (RR) (solid) (top)

(b) Correct passives (correct) (lined) vs. Actives-for-passives (A-for-P) (solid) (bottom)

Table 1

Participants' demographic and language testing data

Participants	P1	P2	P3	P4	P5	P6	P7	P8	P9	Mean
Demographic variables										
Age	66	51	60	58	51	53	38	38	59	52.67
Gender	M	M	M	M	M	M	M	M	F	
Education (year)	18	12	18	19	18	16	18	18	19	17.33
Years post-onset	13	1	5	17	6	17	4	4	3	7.78
Language variables										
Western Aphasia Battery										
AQ	76.4	74.1	74.5	78.5	82.4	79.3	74.4	81.2	71.2	76.89
Fluency	4	5	4	4	5	6	4	4	5	4.56
Comprehension	9.2	8.55	8.95	9.85	9.8	7.75	8.6	7.95	8.7	8.82
Repetition	8.4	6.4	9.6	6.4	10	8.3	7.2	8.2	7.6	8.01
Naming	8.6	8.1	6.7	9.5	9.3	8.6	8.4	7.7	7.3	8.24
Northwestern Assessment of Verbs and Sentences (percentage correct)										
SCT - Active	100	100	100	100	80	80	80	100	80	91.11
SCT – Passive	100	40	40	80	60	40	20	20	40	48.89
SPPT – Active	100	100	100	80	80	100	20	100	40	80
SPPT – Passive	0	40	60	0	20	60	0	60	40	31.11
Northwestern Assessment of Verb Inflection (percentage correct)										
-ing	N/A	80	93	100	93	100	60	73	67	83.25
-ed	N/A	70	40	20	70	60	100	60	70	61.25

Note: SCT = Sentence Comprehension Test; SPPT = Sentence Production Priming Test

Table 2

Percentage correct for the active and passive conditions

Participants	Active	Passive
P1	40	30
P2	90	68
P3	44	15
P4	68	25
P5	100	90
P6	85	45
P7	75	45
P8	68	11
P9	35	25
Mean	67	39

Table 3

Number of errors by error type for the active and passive conditions

Participants	Active condition					Passive condition				
	RR	P-for-A	Morph	Lexical	Others	RR	A-for-P	Morph	Lexical	Others
P1	4	4	0	0	4	1	9	1	2	1
P2	1	0	0	1	0	1	0	0	2	3
P3	0	0	0	8	2	6	4	0	5	2
P4	3	0	0	1	2	9	6	0	0	0
P5	0	0	0	0	0	1	1	0	0	0
P6	2	0	0	1	0	5	1	3	1	1
P7	1	1	3	0	0	5	2	3	0	1
P8	1	0	0	2	3	6	11	0	0	0
P9	2	6	1	3	0	7	1	2	2	3
Total	14	11	4	16	11	41	35	9	12	11

Note: RR = role reversal errors; P-for-A = passives for actives; Morph = grammatical morphology errors; Lexical = incorrect lexical items; A-for-P = actives for passives

Table 4

Gaze duration to N1 produced in milliseconds by speech region in correct passives, RRs, and actives-for-passives

Participants	P1	P2	P3	P4	P5	P6	P7	P8	P9	Mean
Correct Passives										
PRE N1	915	950	1446	1378	1419	984	1231	1115	2509	1327
N1-V	804	97	259	397	297	259	334	279	704	381
V-N2	133	25	167	147	243	100	16	351	200	153
RRs										
PRE N1	1579	2529	2198	2877	1990	2044	1942	1796	5110	2452
N1-V	918	1237	734	704	812	1107	1061	810	3553	1215
V-N2	19	5	40	394	17	104	113	393	1	120
Actives-for-Passives										
PRE N1	725	N/A	938	1226	1427	1210	689	1109	2461	1223
N1-V	597	N/A	676	954	1329	874	898	806	1793	991
V-N2	791	N/A	0	10	125	107	11	700	106	231

Appendix A

List of prime sentences (A = Active; P = Passive)

Trial No.	Prime type	Prime sentence
1	A	The brother is tickling the sister.
2	P	The mouse is kicked by the turtle.
3	P	The boy is saved by the hunter.
4	A	The student is painting the teacher.
5	P	The chicken is followed by the bird.
6	A	The boss is biting the worker.
7	A	The golfer is lifting the lady.
8	P	The boy is covered by the girl.
9	P	The girl is dragged by the boy.
10	P	The patient is examined by the doctor.
11	A	The bear is squirting the ape.
12	P	The writer is grabbed by the scholar.
13	P	The fairy is buried by the witch.
14	A	The sheep is watching the goat.
15	P	The driver is poked by the boy.
16	A	The boy is kissing the girl.
17	P	The puppy is licked by the kitten.
18	P	The woman is carried by the man.
19	A	The dancer is greeting the artist.
20	A	The man is hugging the woman.
21	P	The lady is crowned by the man.
22	A	The artist is touching the musician.
23	P	The taxi is towed by the car.
24	A	The uncle is serving the aunt.
25	A	The coach is patting the player.
26	P	The thief is arrested by the officer.
27	P	The girl is punched by the boy.
28	A	The son is squeezing the mother.
29	A	The man is tripping the woman.
30	A	The fox is leading the wolf.
31	P	The lawyer is pinched by the judge.
32	A	The woman is scolding the man.
33	P	The monster is pulled by the angel.
34	P	The lamb is killed by the wolf.
35	A	The doctor is calling the nurse.
36	P	The servant is shoved by the guest.
37	A	The minister is hitting the bride.
38	A	The banker is chasing the client.
39	P	The boy is stabbed by the friend.

Trial No.	Prime type	Prime sentence
40	A	The father is weighing the mother.

Appendix B

List of target events (A = Active; P = Passive)

Trial No.	Sentence type	Target picture
1	A	The girl tickling the boy
2	P	The rabbit kicking the squirrel
3	P	The man saving the woman
4	A	The mother painting the child
5	P	The pig following the cow
6	A	The girl biting the boy
7	A	The man lifting the woman
8	P	The husband covering the wife
9	P	The princess dragging the prince
10	P	The girl examining the boy
11	A	The mouse squirting the turtle
12	P	The man grabbing the woman
13	P	The boy burying the girl
14	A	The dog watching the cat
15	P	The woman poking the man
16	A	The lady kissing the pilot
17	P	The dog licking the cat
18	P	The chef carrying the waiter
19	A	The girl greeting the boy
20	A	The baby hugging the grandpa
21	P	The queen crowning the king
22	A	The girl touching the boy
23	P	The jeep towing the van
24	A	The wife serving the husband
25	A	The man patting the woman
26	P	The boy arresting the girl
27	P	The runner punching the swimmer
28	A	The woman squeezing the man
29	A	The priest tripping the rabbi
30	A	The goose leading the duck
31	P	The woman pinching the man
32	A	The drummer scolding the singer
33	P	The boy pulling the girl
34	P	The lion killing the tiger
35	A	The woman calling the man
36	P	The girl shoving the boy
37	A	The wrestler hitting the boxer
38	A	The boy chasing the girl
39	P	The cowboy stabbing the farmer

Trial No.	Sentence type	Target picture
40	A	The girl weighing the boy

Appendix C

Examples of incorrect responses by error type

Error type		Target response	Incorrect response
Grammatical morphology	Active condition	The woman is squeezing the man.	The mo mother is squeezing *of* the the father.
	Passive condition	The wife is covered by the husband.	The wife is cover_ by the man.
Role Reversal (RR)	Active with RR	The girl is biting the boy.	The *boy* is biting the *girl*.
	Passive with RR	The uncle is served by the aunt.	The *aunt* is sered by the *uncle*.
Sentence Type	Passive-for-Active	The mother is painting the child.	The s- boy is painted by the mother.
	Active-for-Passive	The cat is licked by the dog.	(The uh) the dog is licking the cat.
Incorrect lexical item	Incorrect noun	The swimmer is punched by the runner.	The swimmer is punched by the uh *doctor*.
	Incorrect verb	The priest is tripping the rabbi.	The priest is *pinching* the rabbi.
	Incorrect verb argument structure	The girl is greeting the boy.	The girl is *saying* hi to the boy.
	Perseveration of prime	The squirrel is kicked by the rabbit.	The *mouse* is kicked by the rabbit.
Others	Incomplete sentence	The man is poked by the woman.	The boy is