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The forgotten grammatical category: Adjective use in agrammatic aphasia

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Abstract

Background—In contrast to nouns and verbs, the use of adjectives in agrammatic aphasia has not been systematically studied. However, because of the linguistic and psycholinguistic attributes of adjectives, some of which overlap with nouns and some with verbs, analysis of adjective production is important for testing theories of word class production deficits in agrammatism.

Aims—The objective of the current study was to compare adjective use in agrammatic and healthy individuals, focusing on three factors: overall adjective production rate, production of predicative and attributive adjectives, and production of adjectives with complex argument structure.

Method & Procedures—Narratives elicited from 14 agrammatic and 14 control participants were coded for open class grammatical category production (i.e., nouns, verbs, adjectives), with each adjective also coded for its syntactic environment (attributive/predicative) and argument structure.

Outcomes & Results—Overall, agrammatic speakers used adjectives in proportions similar to that of cognitively healthy speakers. However, they exhibited a greater proportion of predicative adjectives and a lesser proportion of attributive adjectives, compared to controls. Additionally, agrammatic participants produced adjectives with less complex argument structure than controls.

Conclusions—The overall normal-like frequency of adjectives produced by agrammatic speakers suggests that agrammatism does not involve an inherent difficulty with adjectives as a word class or with predication, or that it entails a deficit in processing low imageability words.

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However, agrammatic individuals' reduced production of attributive adjectives and adjectives with complements extends previous findings of an adjunction deficit and of impairment in complex argument structure processing, respectively, to the adjectival domain. The results suggest that these deficits are not tied to a specific grammatical category.

Keywords

agrammatic aphasia; grammatical categories; adjectives; narrative speech; argument structure; adjunction

1. Introduction

Over the last decades, much research has examined how processing and production of different grammatical categories are affected in agrammatic aphasia. One prominent finding, which has been reported repeatedly, is that many individuals with agrammatism have difficulty with verb as compared to noun retrieval, both in confrontation naming and in sentence production, where main verbs are often omitted (Myerson & Goodglass, 1972; Miceli, Silveri, Villa, & Caramazza, 1984; Miceli, Silveri, Nocentini, & Caramazza, 1988; Semenza, Luzzatti, & Carabelli, 1997).

Interestingly, in contrast to this extensive literature, little research has focused on the third major grammatical category in human languages, i.e. adjectives. Though variable, the frequency of adjectives in different corpora is around 7% (Hudson, 1994), thus this part of speech constitutes a substantial proportion of language. The few mentions in the literature of adjective production in agrammatic aphasia are mostly anecdotal, and agrammatic patterns reported differ across studies. While some studies suggest production patterns similar to that of cognitively healthy speakers and, in some cases, even over-production of adjectives by agrammatic individuals (Benson & Ardila, 1996; Varley & Siegal, 2000), others find that agrammatic aphasia is characterized by a paucity of adjectives (Bernstein, 2010; Menn, 2004).

In the present paper we investigated adjective use in spontaneous speech in agrammatic aphasia, in order to determine whether and how it differs from adjective use in the speech of cognitively healthy speakers. In addition to being interesting in itself, the study of adjectives in aphasia can shed light on several broader questions having to do with agrammatism. In the following subsections we present these questions and discuss how adjectives can contribute to answering them.

1.1 The source of selective verb deficits in agrammatic aphasia

The finding that verb production is often impaired in agrammatic aphasia has been accounted for in numerous ways. In a number of papers, Bird and coworkers argue that agrammatic speakers' difficulty with verbs can be reduced to a general problem with less imageable concepts (Bird, Howard, & Franklin, 2000, 2003). Since verbs do not refer to concrete objects, they are harder to process than nouns, which often do. The authors further suggest that some patients' verb impairment may be due to damage to functional semantic features (in the sense of Warrington & Shallice, 1984), such that actions, mainly defined by

functional properties, are difficult to process. In contrast, other authors have suggested that the primary reason for verb impairment is grammatical, rather than semantic. Caramazza & Hillis (1991) and Hillis & Caramazza (1995) suggest that word forms in a specific grammatical category can be selectively impaired. In addition, Shapiro and colleagues (Shapiro & Caramazza, 2003; Shapiro, Shelton, & Caramazza, 2000) propose that verb impairments may stem from a morpho-syntactic deficit, namely difficulty with person agreement. A similar explanation is offered by Friedmann (2000), who argues that the functional heads relevant for agreement and tense inflection are missing in the syntactic structures generated by agrammatic individuals. Another account of verb deficits in agrammatism focuses on the special role of verbs in sentences, namely the fact that the verb is typically the sentential predicate, assigning thematic roles to the noun phrases accompanying it. Luria (1970) proposed that the basic problem in agrammatism is a loss of predication, namely an inability to establish a relation between a predicate and its subject. Along a similar line, the fact that verb production in agrammatism becomes progressively more damaged as the number of thematic roles of the verb increases (Kim & Thompson, 2000, 2004; Thompson, Lange, Schneider, & Shapiro, 1997), coupled with the fact that nouns typically do not assign thematic roles, indicates that verb production deficits may stem from the argument structure complexity associated with verbs (see Kauschke & Stenneken, 2008).

The debate with regard to the source for the verb-noun processing dissociation has been ongoing for decades and is still not settled. One of the reasons for this is that nouns and verbs differ on numerous dimensions - imageability, agreement, predication, etc. - and thus any difference between the categories can be attributed to any of these aspects. Adjectives can shed new light on this issue, since they share certain properties with nouns, and others with verbs. Adjectives are like nouns in that they do not inflect for tense, and do not show person or gender agreement, at least in English (e.g. 'I am/you are/he is/she is *tall*'). They also resemble nouns in not denoting actions (but rather properties or states), thus arguably not relying on functional semantic features. On the other hand adjectives, like verbs, prototypically function as sentential predicates, predicated over the subject. They are also verb-like in that many of them are less imageable than concrete objects (consider e.g. *married*, *ready*, *sorry* and *jealous*, among many others).

Given this, knowing whether adjective production is spared or impaired in agrammatic aphasia can provide valuable information with regard to the source of verb production deficits. Despite the potential for adjectives to inform word class production deficits in aphasia, few studies have attempted to quantify adjective production abilities in aphasic individuals. In one study Menn (1990) analyzed narratives elicited from two agrammatic English speakers, noting their proportion of adjective (A) compared to verb (V) use (i.e., the A:V ratio). In the two agrammatics' narratives, A:V was 6:26 in one, and 5:7 in the other; in two healthy controls, the proportions were 4:14 and 7:34. Notably, the small sample size in the study makes it hard to draw strong conclusions with regard to adjective production in aphasia.

In the present study, we compared the proportion of adjectives used by agrammatic patients to that used by cognitively healthy controls. If adjectives are spared in patients' speech, this

means that agrammatic individuals do not have an inherent problem with predication, nor with less-imageable categories, as these two properties are shared by adjectives and verbs. Rather, the deficit in verb production would be attributed to the complex morpho-syntax of verbs, or to their action semantics. In contrast, if adjectives are impaired in agrammatism, the problem with verbs is likely to indeed be attributed to predication, or to low imageability, as these traits characterize adjectives as well.

Investigation of adjective use in agrammatism can also potentially inform models of the neural organization of grammatical category information. In the last few decades, extensive research has aimed to specify the brain regions subserving noun and verb processing (for reviews, see Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011). While the traditional fronto-temporal dichotomy hypothesis (Damasio & Tranel, 1993) held that verb impairments are associated with frontal lesions, whereas noun impairments arise as a result of temporal lesions, much subsequent research has undermined this proposal. In particular, as argued by Crepaldi et al. (2011), verb processing seems to be supported by a more diffuse fronto-temporo-parietal network. It is probable that different parts of this network are involved in different aspects of verb processing, i.e. action semantics, inflectional morphology, argument structure, etc. For example, action knowledge seems to be supported by fronto-parietal regions, including the motor cortex (Gerfo et al., 2008; Oliveri, Romero, & Papagno, 2004); processing of low imageability words activates the left inferior frontal gyrus (e.g. Binder, Westbury, McKiernan, Possing, & Medler, 2005; Fiebach & Friederici, 2004; Hoffman, Jefferies, & Lambon Ralph, 2010; Wise et al., 2000); and verb argument structure processes engages frontal-temperoparietal network (see Meltzer-Asscher & Thompson, 2014, for review). Since processing of adjectives engages certain mechanisms involved in verb processing and others involved in noun processing, elucidating what brain regions are associated with adjective processing can contribute to our understanding of the functional neuroanatomical basis for noun and verb processing.

1.2 Adjunction deficits in agrammatism

Numerous studies have established that adjuncts, compared to verb arguments, are computationally expensive for cognitively healthy individuals (e.g. Boland, 2005; Kennison, 2002; Liversedge, Pickering, Branigan, & Van Gompel, 1998; Schütze & Gibson, 1999). There is some evidence for this in agrammatic aphasic individuals as well, although mixed findings have been reported. For example, Canseco-Gonzalez, Shapiro, Zurif, & Baker (1990) observed that verb learning was disrupted in aphasic participants when adjuncts, compared to arguments, were provided in a visually-based artificial language learning task. Lee & Thompson (2011) also found, in an eye-tracking production study, that adjuncts induced greater processing cost (reflected in longer gaze durations and gaze shifts) than arguments, in both healthy and agrammatic speakers. It can be hypothesized that agrammatic speakers, whose lesions often include portions of the left inferior frontal gyrus (IFG), are impaired on adjunct attachment since this process relies heavily on the IFG, which has been associated with syntactic structure building (Grewe et al., 2005; Friederici, Ruschemeyer, Hayne, & Fiebach, 2003 and others; see review in Friederici, 2011). However, in another study on adjunction in aphasia, Byng & Black (1989) found an

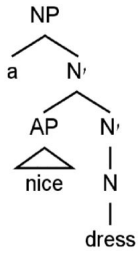
advantage for production of adjuncts over arguments in three nonfluent aphasic patients. It is thus unclear to what extent agrammatic individuals experience difficulty with adjunction. Further, the aforementioned studies all examined verb phrase adjuncts (e.g. 'The man cooked the fish *in the kitchen*'). Even if an adjunction deficit exists in this context, it has yet to be determined whether it extends to other structures involving adjunction.

Adjectives are relevant to this discussion since they may function both as predicates and as attributes. In their *predicative* use (1a), adjectives form the main predicate in the sentence, denoting some property of the sentential subject ('Cinderella's dress', in 1a). In English, this often means that they follow a copula. In their *attributive* use (1b), adjectives form part of a noun phrase, modifying its head noun. Attributive adjectives were traditionally and are still often assumed to be merged as adjuncts (2) (see e.g. Chomsky, 1981). Thus, a deficit in the production of attributive adjectives may reflect a general problem with the adjunction mechanism.

1. **a.** Predicative use: Cinderella's dress is *nice*.

b. Attributive use: Cinderella has [NP a *nice* dress].

2.



In the last couple of decades, it has been proposed by several authors that adjectives and adverbs, as well as other verb phrase "adjuncts" such as locative and temporal PPs, are not attached to the syntactic tree by adjunction, but rather occupy the specifier position of dedicated functional heads in the noun and verb phrase, respectively (Alexiadou, 1997; Cinque, 1994; 1999, 2004). These authors assume a hierarchy of functional heads determining the order of attributive adjectives in the noun phrase. For example, Cinque (1994) proposes the following hierarchy: possessor > cardinal > ordinal > quality > size > shape > color > nationality (e.g. 'his three other beautiful big square red Italian vases'). Importantly, other authors believe that the adjunction analysis is the correct one, and argue that analyses such as Cinque's lead to an inflation of functional heads which duplicate independently motivated semantic distinctions (Ernst, 2002; Haider, 2000; Maienborn, 2001).

If one assumes that adjectives, adverbs and locative/temporal modifiers occupy specifiers of functional heads, rather than adjoined positions, then difficulties with these categories in aphasia could reflect not a deficit in adjunction, but rather a problem with projecting the higher functional heads in the noun and verb phrase, reminiscent of Friedmann and Grodzinsky's (1997) Tree Pruning Hypothesis with regard to the structure of CP. This analysis would further predict that if higher heads show a deficit, lower ones should show one too, but not vice versa.

Several studies have focused on predicative and attributive use of adjectives in aphasia. Menn (1990) reports predicative and attributive adjective use in the narratives of the two agrammatic speakers, mentioned above. One agrammatic speaker produced 13 predicative adjectives and only 3 attributive adjectives, but the other produced 6 predicative and 7 attributive adjectives (though the latter were not always produced correctly). Again, the small sample size limits the conclusions that can be drawn from these data.

Kolk (1978) also examined attributive adjective processing, reporting the results of a study testing three severe and three recovered agrammatic patients in a "judgment of sentence structure" task. Participants were presented with a sentence containing attributive adjectives, e.g. "Old sailors tell sad stories", and asked to point to the two words they thought "go best together". Presumably, these judgments reflect the ability to build correct sentence structures, e.g. [[old sailors] [tell [sad stories]]. The results showed that whereas participants in the recovered group tended to pair the attributive adjective with the noun it modified (e.g. "old" with "sailors"), the same was not true for the severe group. The author suggested that agrammatic individuals construct impoverished syntactic structures, and that adjectives are not represented because they give rise to complex structures. While Kolk's results are indicative of difficulty with attribution, it can be argued that the meta-linguistic task chosen, namely judgment of sentence structure, may not reflect patients' actual processing. Several authors have demonstrated asymmetries between automatic processing and controlled, metalinguistic performance in aphasia, and argued that the use of meta-language may be drastically limited, even when verbal communication is relatively spared (Jakobson, 1963; Lebrun & Buyssens, 1982; Rigaudeau-McKenna, 1998; Stark, 1988).

In a more recent study, de Roo, Kolk, & Hofstede (2003) investigated predicative and attributive adjective production in Dutch-speaking agrammatic patients using a picture description task. Results showed higher proportions of attributive adjective use in controls than in the agrammatic participants. The authors proposed that attributive adjectives involve a higher processing load than predicative ones, and are thus avoided by patients.

In contrast to these results, Friederici & Frazier (1992) addressed the difference between predication and attribution in a sentence picture matching experiment, with seven Broca's aphasic individuals. Stimuli were German sentences with either small clause predication (e.g. 'The man paints the door green') or attribution (e.g. 'The man paints the green door'). The authors found around 30% incorrect answers in both conditions, with no significant difference between the two.

In the current study, we aimed to evaluate the attributive and predicative usage of adjectives in agrammatic speakers. If agrammatic individuals tend to avoid using adjectives attributively, this may suggest a problem with the adjunction mechanism, manifesting itself in NP adjunct deficits (in addition to VP adjuncts, as suggested by previous literature) or alternatively, given that the deficit obeys the hierarchical order of assumed functional heads, it may reflect pruning of the noun phrase (parallel to a hypothesized pruning of the verb phrase). If, on the other hand, attributive adjectives are unimpaired, adjunction, or the entire projection of the noun phrase, must be assumed to be spared.

1.3 Argument structure deficits in agrammatism

Finally, adjectives provide a testing ground for the argument structure production deficits seen in many individuals with agrammatic aphasia. Research in aphasia has shown that as the number of thematic roles increases, verb production becomes more difficult for agrammatic aphasic patients. This pattern has been noted in verb naming in different languages (DeBlesser & Kauschke, 2003; Kemmerer & Tranel, 2000; Kim & Thompson, 2000, 2004; Kiss, 2000; Thompson, Lange, Schneider, & Shapiro, 1997; Luzzatti et al., 2002), as well as in sentence production tasks, i.e. fewer correct sentences are produced with ditransitive and transitive verbs than with intransitive verbs (Dragoy & Bastiaanse, 2010; Thompson et al., 1997). Thompson & Meltzer-Asscher (2014) propose a neurocognitive model of verb argument structure processing, arguing that this processing is subserved by three left-lateralized regions: the angular gyrus (AG), the IFG, and the posterior middle and superior temporal gyri (MTG and STG, respectively). While the AG is a crucial region for representation of lexical argument structure information, the IFG is involved in syntactic structure building necessitated by the projection of arguments (as well as in syntactic movement, when it occurs), and the posterior MTG and STG play a role in the integration of the verb with its arguments.

One question that has not been completely explored in the context of argument structure deficits in agrammatism is whether the observed argument structure complexity effect is a verb-specific phenomenon, or whether it is general and independent of lexical category. Collina, Marangolo, & Tabossi (2001) and Tabossi et al. (2010) have shown that agrammatic Italian speakers have difficulty with argument-taking nouns (e.g. *pianto* ‘crying’) as opposed to non-argumental nouns (e.g. *medaglia* ‘medal’). However, the effect of argument structure complexity has not been investigated in the adjectival domain.

Adjectives may take different types of arguments, as exemplified in (3) (for discussion of the argument structure of adjectives, see Meltzer-Asscher, 2010, 2011). In the overwhelming majority of cases, arguments are selected by predicative, rather than attributive, adjectives. Additionally, it is rarely the case that an adjective obligatorily selects a complement. Ordinarily, adjectives select optional complements, and are grammatical with no complementation (compare (3a), where the complement is obligatory, to (3b-e), where the complements are optional).

(3)

a. She was fond [of animals].

b. She was worried [about the time].

c. She was nice [to her mother].

d. He was excited [that the prince was throwing a party].

e. It’s wonderful [that Cinderella went to the ball].

In the current study, we examined whether the adjectives produced by agrammatic participants paralleled those produced by healthy speakers with regard to their argument structure complexity. Specifically, we investigated i) whether the predicative adjectives

produced by agrammatic speakers parallel those produced by controls in their capacity to select arguments, i.e. in the complexity of lexical information associated with them, and ii) whether those predicative adjectives that select for optional complements in fact appear with a complement when they are used in the narratives. If patients exhibit lower argument structure complexity than controls, this suggests that the argument structure deficit observed in agrammatism is likely a general impairment, not associated with verbs only.

2. Method

2.1 Participants

Narrative samples were elicited from 14 agrammatic speakers and 14 cognitively healthy controls, all native English speakers with normal hearing and normal or corrected-to-normal vision. The healthy participants had no history of speech or language disorder, or a neurological or psychiatric illness. Aphasic participants were recruited from the subject pool of the Aphasia and Neurolinguistics Research Laboratory in, in the Center for the Neurobiology of Language Recovery at Northwestern University. The study was approved by the IRB at Northwestern University and all participants gave their written informed consent prior to the study.

Each group consisted of 10 male and 4 female participants. The two groups did not differ in age (agrammatic M = 57 y, control M = 62 y, t (26) = 1.6, p = .1). However, the agrammatic participants were on average more educated than control participants (agrammatic M = 17.2 y, control M = 15.4 y, t (26) = 2.22, p = .035).

Participants were classified as agrammatic based on their performance on the Western Aphasia Battery (WAB, Kertesz, 2007) and the Northwestern Assessment of Verbs and Sentences (NAVS, Thompson, 2011), as well as production patterns seen in spontaneous speech. Agrammatic participants presented with mild-to-moderate aphasia (mean WAB-AQ = 76.2, range 65.9 - 85.4), with speech characterized by low fluency (mean WAB fluency score = 4.6, range 4 - 6). Their narratives included large proportions of ungrammatical sentences, due to omission of grammatical elements, among other reasons (mean % grammatical sentences = 42.6, range 9.1 - 87). In contrast, control participants were at ceiling on the WAB (out of the 7 controls to which the WAB was administered, 6 evinced WAB-AQs of 100% and 1 scored 99.6%), and their narratives included almost exclusively grammatical sentences (mean % grammatical sentences = 95, range 88 - 100).

Scores of the agrammatic individuals on the Northwestern Naming Battery (NNB, Thompson & Weintraub (2014) (also see Thompson, Lukic, King, Mesulam, & Weintraub, 2012b) indicated a significant advantage in noun naming over verb naming (noun M = 90.9%, verb M = 82.7%, paired-samples t (13) = 2.24, p = .004). Verb naming was found to be impaired also on the Verb Naming Test (VNT) of the NAVS, with mean correct naming at 73%. On the Verb Argument Structure Production Test (ASPT) of the NAVS participants showed relatively spared verb argument structure production, performing on average at 92.5% (SD = 5%). However, they evinced verb argument deficits in their narrative production (see subsection 3.3 in the Results section below). In contrast, control participants performed near ceiling on these tests,[1] and the difference between the agrammatic and

control group was significant for all measures (two-tailed t-test, *p*'s < .01). Aphasic participants' language test scores are presented in Table 1.

All of the aphasic participants suffered left-hemisphere strokes, except for one who suffered an open head injury, on average 7 years and 3 months prior to narrative elicitation (range: 2y;2m - 20y;3m). Anatomical scans were performed for 9 of the 14 participants, and lesion descriptions were available for 2 additional participants, showing variation in the location of the lesion and its extent across participants. All patients had lesions involving portions of the left inferior frontal gyrus, as well as temporal regions. Selected slices from these patients' T1 MRI images are presented in Figure 1, and a brief description of the participants' lesions is provided in Table 2.

Participants were selected for inclusion in the study only if their narrative included at least 75 words.

2.2 Narrative elicitation and coding

Participants were given a picture book depicting the story of Cinderella, without any text. They were asked to study the book, and then re-tell the story of Cinderella. Prior to participants' beginning their narratives, the book was removed, but participants were permitted to look at it as needed. Fergadiotis & Wright (2011) discuss the possibility that the lack of pictorial support may adversely affect aphasic more than cognitively healthy speakers, since it may force them to allocate more resources, otherwise dedicated to lexical access, to memory and organizational processes, as well as eliminating conceptual priming which visual illustrations provide. Although this may be the case, there is no reason to believe that this effect interacts with word class, e.g. that it affects adjective production differently than verb or noun production.

The narratives were recorded using Praat software (version 5.0, http://www.praat.org). All language samples were transcribed, segmented into utterances, and coded by experienced researchers in the Aphasia and Neurolinguistics Research Lab at Northwestern University. Coding involved several levels of analysis, including the verb argument structure level, in which each verb was coded for its argument structure (e.g. intransitive, optional transitive, obligatory transitive, etc.) and argument realization (i.e. which arguments actually appeared in the utterance). For detailed description of the coding method, see Thompson et al. (1995) (see also Thompson et al. 2011, 2012a).

For the current study, we additionally tallied the number of adjectives, lexical nouns (excluding pronouns), and verbs produced in all utterances in the narrative, both grammatical and ungrammatical. Copulas were not included in the verb count, since they very often co-occur with predicative adjectives (e.g. 'The dress was beautiful'). Passive and present participles (e.g. 'married', 'convincing') were coded as either verbs or adjectives according to syntactic diagnostics proposed in the literature (e.g. Levin & Rappaport, 1986;

[1]Out of the 13 healthy control participants to which the tests were administered, all performed at 100% on the verb portion of the NNB, and all but one scored 100% on the noun portion of the NNB, the NAVS-VNT and the NAVSASPT (with one participant scoring 98% on the NNB-nouns, a different participant scoring 95.5% on the VNT, and another participant scoring 96.9% on the ASPT).

Meltzer-Asscher, 2010; Wasow, 1977). In the rare cases where the diagnostics could not determine the grammatical category of the participle, we relied on its semantics, adopting the assumption that verbs denote events, whereas adjectives denote states or properties. Thus, for example, in the utterance 'It was made of glass', referring to Cinderella's shoe, the participle *made* was coded as an adjective, since the sentence reports a property of the shoe, rather than the event in which it was made by someone. Semantic judgments rather than syntactic diagnostics were used in a total of 11 participles in the agrammatic participants' narratives, and 21 participles in the controls' narrative, constituting less than 2% of the verbs and adjectives produced.

Each adjective produced was further coded as either predicative or attributive. Following the literature, adjectives were counted as predicative if they appeared in one of the following configurations:

- **i.** Following a copula (e.g. 'Cinderella was *beautiful'*, also e.g. 'Cinderella wasn't very *beautiful'*)
- **ii.** In a small clause (e.g. 'He considered her *beautiful'*)
- **iii.** After a raising verb (e.g. 'She seemed *tired'*)
- **iv.** In a resultative phrase (e.g. 'They painted the carriage *yellow'*)
- **v.** In a descriptive secondary predicate (e.g. 'She arrived *dressed up*')
- **vi.** After a control verb (e.g. 'They felt *sorry'*).

Adjectives were counted as attributive when appearing as noun modifiers, either prenominally (e.g. 'a *beautiful* girl'), or postnominally (e.g. 'something *nice*'). Adjectives for which no clear decision could be made (e.g. adjectives in ungrammatical utterances, such as 'That were everything nasty') were coded neither as predicative nor as attributive.

Additionally, every predicative adjective was coded as either able or unable to select a complement, regardless of its use in the current narrative (e.g. *wonderful* can take a complement, see (2e) above, whereas *tiny* cannot), and for whether it actually appeared with a complement. Finally, every attributive adjective was coded for its type, or position in the hierarchy of adjectives proposed by Cinque (1994), namely ordinal, quality, size, shape, color or nationality.

2.3 Imageability rating

To investigate the imageability of the adjectives produced, we conducted a post-hoc imageability survey. The adjectives produced by both participant groups were pooled and then divided between two lists, one containing 51 adjectives and the other - 52. Each list was randomized twice to create two different orders, resulting in four questionnaires. Participants were asked to rate the ease or difficulty with which the adjectives in the questionnaire aroused mental images, on a 1 to 7 scale. For ambiguous adjectives, e.g. *fair*, a usage example was given that exemplified the meaning used in the elicited narrative. Twenty participants filled out the survey, 5 per questionnaire. The mean age of participants was 46.4 years.

3. Results

We first calculated the total number of content words per narrative, as the sum of the counts of adjectives, nouns and verbs in the sample (see Table 3). Although the number of content words tended to be somewhat smaller for agrammatic participants than for controls, indicating shorter narratives (agrammatic M = 92.8 words, SD = 41; control M = 144.1 words, SD = 108.1), this difference was not statistically significant (two-tailed t (26) = 1.662, p = .108).

3.1 Overall adjective use

The distribution of the different grammatical categories out of the total number of content words produced is presented in Figure 2. As observed in previous studies, the agrammatic aphasic speakers exhibited an increased N:V ratio, producing more nouns and fewer verbs than controls, with a marginally significant difference between the two groups (mean agrammatic N:V ratio = 1.63, SD = .35; mean control N:V ratio = 1.41, SD = .23; two-tailed t (26) = 1.978, p = .059). With regard to adjectives, there was no significant difference between agrammatic and control participants in the percentage of adjectives out of all content words (agrammatic M = 9.9%, SD = 6.6%; control M = 9.3%, SD = 3.3%, t (26) = .268, p = .791). Likewise, there was no difference between the groups in A:V ratio (mean agrammatic A:V ratio = .30, SD = .24; mean control A:V ratio = .25, SD = .09; t (16.467) = .776, p = .449).

To analyze the imageability of the adjectives produced by the two participants groups, we conducted a t-test comparing the imageability ratings of all the tokens produced (i.e. by calculating a weighted mean and SD, such that each rating was multiplied by the number of times the adjective was produced by participants in the group). There was no significant difference between the imageability of the adjectives in the narratives of aphasic and control participants (mean agrammatic imageability rating = 4.81, SD = 2.03, mean control imageability rating = 4.79, SD = 2.28, two-tailed t (126) = .046, p = .963). The adjectives produced by the two participant groups, their imageability ratings, and the number of times they were used, appear in the Appendix.

3.2 Use of predicative and attributive adjectives

Next, we examined the use of adjectives predicatively and attributively in the two participant groups. Results are shown in Figure 3. Compared to controls, the agrammatic participants exhibited a significantly greater proportion of predicative adjectives (agrammatic M = 57.6%, SD = 28.6%; control M = 35.4%, SD = 18.9%, two-tailed t (26) = 2.416, p = .023) and a lower proportion of attributive adjectives (agrammatic M = 31.2%, SD = 26.6%; control M = 64.1%, SD = 18.4%, two-tailed t (26) = −3.808, p = .001).

Most predicative adjectives produced by both groups appeared in a copular construction, though this was especially conspicuous in the agrammatic group (58 out of 64 in the agrammatic narratives, 60 out of 81 in the control narratives). The remainder of the predicative adjectives produced by agrammatic participants either followed a control verb (1 case), or appeared as part of a *get*-passive, a descriptive secondary predicate (2 cases each),

or a small clause (1 case). In the control group, the remainder of the adjectives likewise appeared in small clauses, descriptive secondary predicates (1 case each), or after control verbs (3 cases), and in addition, three predicative adjectives appeared as complements of raising verbs. Notably, thirteen predicative adjectives appeared in the *get*-passive.

We also computed correlations between verb and adjective use across individuals in the two groups. For this, we calculated correlations between the percentage of verbs and the percentage of predicative adjectives produced. We used predicative adjectives for this analysis because these adjectives function as sentential predicates, as do verbs (whereas attributive adjectives appear as noun modifiers, a position not available for verbs). In this regard, predicative adjectives "compete" syntactically and semantically with verbs. The results are presented in Figure 4. Although significant correlations were not found for either participant group, a positive trend was found for the control speakers (Pearson $r = .315$, $p = .272$), whereas a negative trend was found for the aphasic speakers (Pearson $r = -.483$, $p = .080$), suggesting that predicative adjective use increased as verb use decreased in our patient sample.

We also calculated the correlation between the overall number of content words in the narrative and the proportion of attributive adjectives out of all adjectives, in both participant groups. The rationale for this was that speakers with low word counts may employ an 'output economy' strategy, which may extend also to attributive adjectives, which are syntactically optional. We found no correlation between the two measures in any of the participant groups (agrammatic: Pearson's $r = .419$, $p = .136$; controls: Pearson's $r = -.259$, $p = .372$).

We further wanted to investigate whether the deficit in attribution is selective in terms of adjective type, i.e. whether adjectives hypothesized to reside in higher functional projections were more affected in the aphasic group than "lower" adjectives. To do that, we compared the proportion of each attributive adjective type out of all attributive adjectives between the two participant groups. There was no significant difference between the groups on any adjective type (Ordinal adjectives: agrammatic mean = 6.1%, SD = 15.8%, control mean = 9.9%, SD = 16.4%, two tailed $t(22) = -.564$, $p = .579$; Quality adjectives: agrammatic mean = 75.2%, SD = 25.3%, control mean = 77.7%, SD = 17.6%, two tailed $t(22) = -.286$, $p = .778$; Size adjectives: agrammatic mean = 18,6%, SD = 17.7%, control mean = 9.4%, SD = 13.1%, two tailed $t(22) = 1.472$, $p = .155$; Color adjectives: agrammatic mean = 0%, SD = 0%, control mean = 3.0%, SD = 6.2%, two tailed $t(22) = -1.794$, $p = .096$).

3.3 Argument structure complexity

Finally, we compared both lexical and sentential aspects of argument structure complexity between groups, looking at both verbs and adjectives. For verbs, we examined lexical argument structure complexity by calculating how many of the verbs produced by each participant group were intransitive, transitive, or ditransitive. There was no difference between the two groups in the proportion of intransitive or transitive verbs produced (Intransitive: agrammatic M = 29.8%, SD = 16%, control M = 29.8%, SD = 8.4%, two-tailed $t(26) = 0$, $p = 1$; Transitive: agrammatic M = 65.6%, SD = 15.8%, control M = 60.9%, SD = 10.1%, two-tailed $t(26) = .953$, $p = .349$). However, the two groups differed on the

proportion of ditransitive verbs produced, with controls producing significantly more ditransitives than agrammatic participants (agrammatic M = 4.1%, SD = 5.8%, control M = 9.4%, SD = 4.5%, two-tailed t (26) = 2.668, p = .013).

To investigate the sentential realization of argument structure properties, we calculated the proportion of optionally transitive verbs (e.g. *eat*) which were actually produced with a complement in the narrative. We chose optionally transitive verbs as this category closely resembles predicative adjectives, whose second argument is almost always optional. While the difference between the two participant groups did not reach statistical significance, control participants produced more optional complements than agrammatic speakers (agrammatic M = 36.7%, SD = 28.5%, control M = 50.9%, SD = 21.9%, two-tailed t (26) = 1.456, p = .157).

Turning next to adjectives, for the lexical aspect or argument structure information, we looked at the percent of adjectives that can potentially take complements out of all predicative adjectives, namely the proportion of 'optionally transitive' adjectives. A significant difference was found between agrammatic participants and controls, such that the percent of adjectives that select for complements was significantly smaller in the agrammatic than in the control group (agrammatic M = 72.2%, SD = 27.3%; control M = 91.3%, SD = 12.7%, two-tailed t (18.4) = −2.498, p = .022). For the syntactic aspect, we compared the proportion, out of these 'optionally transitive' adjectives, of adjectives actually appearing with complements, in the two participant groups. We found a trend towards agrammatic participants' producing fewer of these adjectives with complements than controls (agrammatic M = 29.2%, SD = 42.3%; control M = 55.5%, SD = 37.3%, t (26) = −1.745, p = .093).

Finally, we performed a correlation analysis between the overall number of content words in the narrative and the number of adjectives produced with complements in it, in both participant groups. Whereas a strong positive correlation was found in the control group (Pearson's r = .941, p < .001), no correlation was found in the agrammatic group (Pearson's r = .176, p = .547).

4. Discussion

In the current study, we investigated agrammatic aphasic speakers' use of adjectives, a little-studied word class in this population. To do so, we compared agrammatic and cognitively healthy individuals' production of adjectives in spontaneous speech as well as their production of nouns and verbs, which have been widely studied in aphasia. We also examined production of adjectives by type (i.e., predicative adjectives and attributive adjectives), and the argument structure of the adjectives produced.

Results showed that agrammatic speakers do not differ from healthy individuals in the overall proportion of adjectives used in their narratives. In both groups, about 9-10% of content words (calculated as the sum of nouns, verbs and adjectives) consisted of adjectives. One implication of this finding is that adjectives, as a general word class, are not impaired in agrammatic aphasia. Further, the similarity between the proportion of adjectives out of all

content words produced by agrammatic and cognitively healthy speakers, and especially the agrammatic speakers' over-production of predicative adjectives, indicates that these speakers retain predication ability, namely the ability to put together a predicate and a subject. This finding suggests that the source of verb deficits in agrammatic aphasia cannot be attributed solely to impairment in predication, as argued by some researchers (see Luria, 1970).

The finding that agrammatic speakers produced adjectives in proportions similar to controls together with the finding that the imageability of the adjectives produced by the two groups was very similar call into question the idea that verb deficits in agrammatism are attributable to the low imageability status of verbs (e.g. Bird et al., 2000, 2002). In our sample, patients produced a myriad of adjectives which exhibit low imageability, e.g. 'done', 'next', 'normal', 'right' and others. This seems to be at odds with the claim that processing of low imageability words recruits the left IFG (Binder et al., 2005; Hoffman et al., 2010), as at least parts of this region were lesioned in our participants. Importantly, however, as noted by Bedny & Thompson-Schill (2006), this claim is based on studies which have either used only nouns, or did not report the grammatical class of the stimuli used. In a semantic judgment task including 100 verbs with increasing imageability ratings (e.g. *consist* < *serve* < *swim*), Bedny & Thompson-Schill found the reverse effect, namely activity in the IFG increased as verb imageability increased. The present findings suggest that production of less imageable adjectives likewise does not necessarily involve the IFG.

In examining production of adjectives by type, we found a greater proportion of predicative adjectives in our agrammatic speakers' narratives compared to the cognitively healthy controls. This may reflect use of predicative adjectives to compensate for verb deficits, i.e. realizing the predicate in the sentence as an adjective rather than a verb (e.g. saying 'Cinderella was sad' rather than 'Cinderella cried').

Conversely, we found that the agrammatic participants in the present study produced fewer attributive adjectives than control speakers. We did not find a differential impairment, such that adjectives hypothesized to reside in higher functional projections according to Cinque's (1994) analysis were more affected than lower ones. The findings thus do not seem to lend strong support to the analysis of attributive adjectives in terms of a hierarchy of functional heads, though they do not rule it out completely, as it could still be the case that such an effect would be detected in a task forcing production of different adjective types. Assuming that attributive adjectives (and adverbs) are attached to the syntactic tree as adjuncts, the finding of an attribution impairment supports previous research showing an adjunction deficit in verb phrases in agrammatism (Canseco-Gonzalez et al., 1990; Lee & Thompson, 2011), and extends it to adjunction in noun phrases. Alternatively, it could be maintained that the higher functional projections in both the noun and the verb phrase are independently damaged in agrammatism.

Alternative, non-structural explanations for the decreased proportion of attributive adjectives in agrammatic speech also are possible. The first is provided by the *Lexical Head Principle* (henceforth LHP) of Martin & Freedman (2001). The authors tested patients with short term memory impairments and unimpaired controls on production of predicative and attributive

adjectives, and found an advantage for predicative adjectives in both groups. Based on this, the authors proposed the LHP, stating that all content words up to and including the head of a phrase must be planned at the lexical/semantic level prior to initiating phonological retrieval. Since in attributive structures, e.g. 'the nice dress', the head of the phrase is the noun 'dress' and it appears at the end of the phrase, both the adjective and the noun need to be planned in advance, increasing processing load. In contrast, in a predicative configuration such as 'The dress is nice' each phrase contains only one content word, and thus no processing difficulty is predicted. Arguably then, a difficulty with attachment of attributive adjectives can be accounted for by the LHP, rather than by an adjunction deficit. Although the LHP can potentially explain why agrammatic speakers tend not to use attributive adjectives, it cannot account for their difficulty with verb phrase adjuncts relative to arguments, as in both structures (e.g. 'eat the fruit' vs. 'eat in bed') the head is phrase-initial, and both include the same number of content words. In the future, it would be interesting to study agrammatic production of attributive adjectives in languages where the adjective follows, rather than precedes, the head noun (e.g. Hebrew). The LHP does not predict that these structures will cause any difficulty, since only one word needs to be planned at a time. On the other hand, if agrammatic patients have a general deficit with adjunction, it will surface also in attribution structures in these languages, since the linear order between the head and the adjunct is irrelevant under this hypothesis.

A second alternative explanation for the fact that attributive adjectives were produced in smaller proportions in our patient sample may be that since speech is in general effortful for agrammatic speakers, syntactically optional elements, including attributive adjectives, are avoided. Attributive adjectives are not necessary for the advancement of the narrative, and in addition, if predicative adjectives are used to replace verbs, the use of the adjective attributively becomes redundant (e.g. agrammatic speakers will produce 'The prince was sad' instead of 'The sad prince was crying'). To test this hypothesis, we computed the correlation between the overall number of content words in the narrative and the proportion of attributive adjectives out of all adjectives, in both participant groups. The rationale for this was that speakers with low word counts are likely those who employ an 'output economy' strategy, avoiding optional elements, and should thus show a low proportion of attributive as compared to predicative adjectives, if the deficit in attribution is to be explained in terms of general economy. However, we did not find a negative correlation between word count and proportion of attributive adjectives, meaning that it was not the case that agrammatic individuals who were more economic in their production tended to avoid attributive adjectives the most. Additionally, it can be noted that despite their syntactic obligatoriness, the information provided by predicative adjectives is in many cases nonessential to the plot, on a par with that provided by attributive adjectives. In fact, the entire sentence built around the adjectival predicate may not be necessary (e.g. 'The ball (uh) saw (uh) this man this prince and (he had uh he uh uh a) prince was just magnificent.'). In the future, we plan to investigate whether production of attributive adjectives is impaired also in a constrained elicitation task, where production economy considerations are irrelevant.

With regard to the neural ramifications of the predicative-attributive asymmetry we have observed, since the participants in our study had lesions extending to the IFG, this result

suggests that the IFG is necessary for adjunct attachment, a syntactically complex operation (Friederici, 2011). Thus, damage to the IFG may lead to an adjunction impairment. However, given that our agrammatic participants presented with large perisylvian lesions, resulting in damage to portions of the neural network for language in temporoparietal as well as frontal regions, it is possible that other brain regions contribute to syntactic adjunction.

Finally, our results show a clear difference between agrammatic and healthy speakers in adjectival argument structure complexity. With regard to the lexical properties of the adjectives used, although both participant groups used many predicative adjectives which can potentially select complements, the proportion of these adjectives was larger in the control group, indicating that controls used adjectives with more complex argument structure representations, namely adjectives which subcategorize for an optional complement. The finding that agrammatic participants had relative difficulty with production of adjectives with complex argument structure (regardless of the actual realization of arguments in the sentence) parallels previous results from the verbal domain, showing deficits of agrammatic speakers in the naming of transitive relative to intransitive verbs (DeBlesser & Kauschke, 2003; Kemmerer & Tranel, 2000; Kim & Thompson, 2000, 2004; Kiss, 2000; Thompson, Lange, Schneider, & Shapiro, 1997; Luzzatti et al., 2002). It is also in line with our participants' performance on verb argument structure in the current task, namely the fact that these speakers used relatively fewer complex verbs, i.e. produced significantly fewer ditransitive verbs than controls. It can be noted that the agrammatic participants in our study performed relatively well, though significantly poorer than controls, on the Argument Structure Production subtest (ASPT) of the NAVS, with mean percent correct at 92.5%, as mentioned in section 2.1 above. This may reflect the fact that in the ASPT, participants are provided with the verb and the arguments, and thus the test does not require verb retrieval, unlike the narrative task.

Further, although the agrammatic participants in our study produced some optionally transitive adjectives with complements (e.g. 'conscious about that', 'angry at this' 'happy to knew Cezerella was the owner of the shoe'), they did so less often than controls, although this trend did not reach statistical significance. This is consistent once again with our results in the verbal domain, showing numerically lower proportions of optional transitive verbs appearing with complements in the agrammatic compared to the control group. The results are also in line with previous findings showing lower percentages of correct productions of sentences with transitive compared to intransitive verbs, mostly due to argument omission (Cho-Reyes & Thompson, 2012; Dragoy & Bastiaanse, 2010; Thompson et al., 1997). As explained in section 1.3, unlike in the verbal domain, adjectives very rarely require arguments. This means that the low proportion of adjectives with complements does not necessarily result in higher proportions of ungrammatical sentences, as would be the case if arguments of obligatorily transitive verbs were omitted.

In this case too, it could be suggested that adjectival complements are avoided simply due to the general effort associated with speech, rather than because of a grammatical deficit. If narratives are to be short, optional complements can be omitted. Indeed, examining our control speakers' production patterns, participants producing shorter narratives also

produced fewer adjectives with complements, as shown by the strong correlation observed between the number of content words and the number of adjectives with complements in their narratives. However, the same pattern was not observed in the agrammatic group, where no such correlation was found. For example, the patient producing the longest story, comprising 190 content words, did not produce any adjectival complement. For comparison, control participants producing narratives of about the same length produced a number of adjectives with complements, e.g. C11, whose narrative contained 177 content words, produced 5 adjectival complements, and C7, with 169 content words, produced 3 of them. It therefore does not seem to be the case that complements to adjectives were avoided as a general speech-reduction strategy.

The finding that argument structure production deficits are not uniquely tied to verbs and extend to the adjectival system in agrammatic aphasia suggests a general deficit with the representation or processing of argument structure information associated with lexical entries of different categories. In terms of the neural substrates of argument structure processing, this suggests that the network proposed by Thompson & Meltzer-Asscher (2014) for verbs may also be engaged more generally for argument structure processing for other grammatical classes. Because the agrammatic participants in our study exhibited lesions involving both frontal and temporoparietal regions, their difficulty with adjectival argument structure is compatible with the idea that the IFG, posterior MTG and STG, and AG, are involved in argument structure processing, regardless of grammatical category. Again, strong conclusions pertaining to the underlying neural networks engaged for adjectival argument structure cannot be drawn based on the present data. However, further research addressing this issue is warranted.

5. Conclusion

Adjectives possess several unique properties that make them an interesting and useful subject matter in the study of aphasia, yet only limited research has focused on this category. Results of the current study show that, overall, the frequency of adjective production in spontaneous speech of agrammatic speakers is similar to that of cognitively healthy speakers, suggesting that agrammatism does not involve a deficit in adjective production (as a word class), predication, or production of abstract words with low imageabilty. The present findings, however, reveal difficulty in the production of attributive adjectives for agrammatic speakers, likely due to a general adjunction deficit. Lastly, the study demonstrates that argument structure complexity compromises agrammatic speakers' production across grammatical categories.

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Appendix

Adjectives used by the two participant groups, with imageability rating and count of tokens for each adjective

Agrammatic			Control		
Adjective	**Imageability rating**	**Count**	**Adjective**	**Imageability rating**	**Count**
adamant	3.5	1	allowed	2.3	1
alike	3.9	1	angry	6.9	1
alone	4.1	1	another	1.8	1
angry	6.9	2	barefoot	6.8	1
awful	4.2	2	beautiful	5.1	17
bad	2.9	2	big	6.8	4
beautiful	5.1	14	certain	2.6	1
big	6.8	7	charming	4.3	3
broken	5.4	1	crestfallen	3.6	1
clear	3.1	1	demanding	3.3	1
conscious	3.1	1	different	2.9	1
despondent	4.7	2	domestic	4.1	1
done	2.2	3	dressed	6.1	1
dressed up	6.3	3	easy	3.2	1
evil	6.5	2	else	1.5	1
friendly	4.3	1	evil	6.5	2
gone	4.2	1	fair	4	1
good	3.4	6	fancy	5.9	2
great	3.3	3	favorite	2.5	1
grown up	5.7	1	freed	4.9	1
handy	3.8	1	friendly	4.3	1
happy	6.7	6	gone	4.2	1
hard	3.4	2	good	3.4	1
horrible	4.8	1	grand	5.5	1
horrified	5.8	1	great	3.3	6
hurried up	5.4	1	happy	6.7	3
jealous	4.7	1	hard	3.4	1
lazy	4.5	1	irate	6.5	1
little	5.5	2	jealous	4.7	2
lost	5.1	1	left	2.8	1
mad	6.3	1	little	5.5	6
magical	6.2	2	loyal	3.1	1
magnificent	4.2	1	made	2.1	1
mean	4	3	magical	6.2	1
mortified	5.6	1	married	5.6	6
nasty	5.1	1	mean	4	6
new	6.2	2	menial	3	1

Agrammatic			Control		
Adjective	**Imageability rating**	**Count**	**Adjective**	**Imageability rating**	**Count**
next	1.8	1	named	1.7	3
nice	4.6	7	nasty	5.1	1
normal	2.4	1	new	6.2	3
older	4.6	1	next	1.8	1
other	1.9	2	nice	4.6	5
perfect	3.3	2	old	6.8	2
pissed	5.1	1	older	4.6	2
poor	4.9	1	original	2.4	1
ready	2.9	1	other	1.9	4
right	2.2	1	overjoyed	6.4	2
sad	6.5	5	pink	6.9	1
sorry	4.7	1	prettier	4.4	1
sound	2	1	pretty	6.9	2
surprised	5.9	1	ready	2.9	2
terrible	4.9	2	required	1.9	1
tiny	6.1	2	sad	6.5	4
upset	6.1	1	shocked	5.8	1
wonderful	3.4	4	simple	3.7	1
young	5.5	1	skeptical	4.2	1
youngest	5.7	1	small	5.9	1
			smitten	4.9	1
			strange	4.8	1
			supposed	1.7	2
			Sure	2	1
			taken	4.1	1
			tattered	6.6	1
			terrible	4.9	3
			turned	2.4	1
			ugly	6	3
			white	6.6	3
			wicked	6.2	11
			wonderful	3.4	2
			worse	3	1
			young	5.5	6

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- The study investigates adjective use in narrative speech in agrammatic aphasia
- Overall agrammatic speakers produce adjectives in similar proportions to controls
- This suggests that verb deficits are not due to predication or low imageability
- Agrammatic speakers show deficits with attribution and argument-taking adjectives
- This extends previous findings from the verbal domain to the adjectival domain

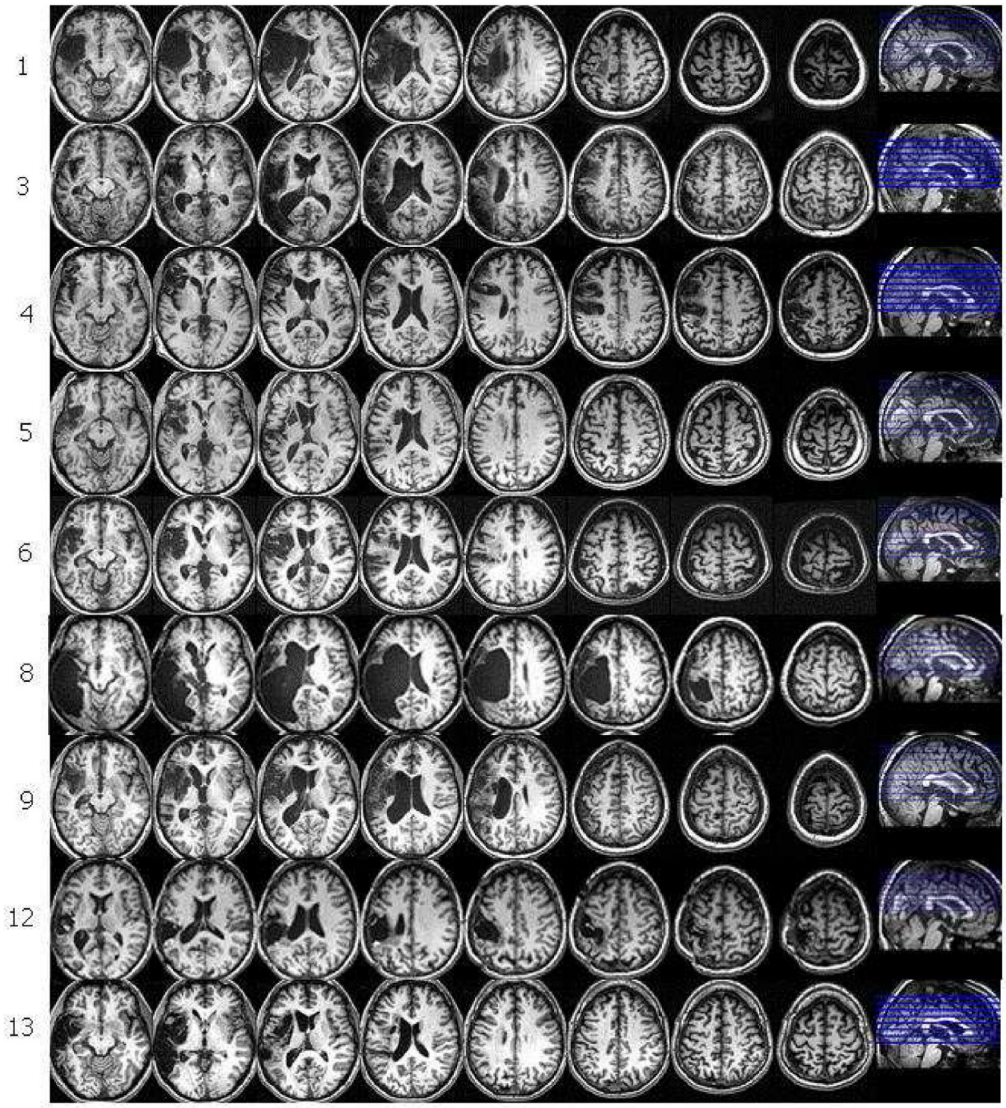

Figure 1.
Selected slices from the T1 MRI images of scanned participants

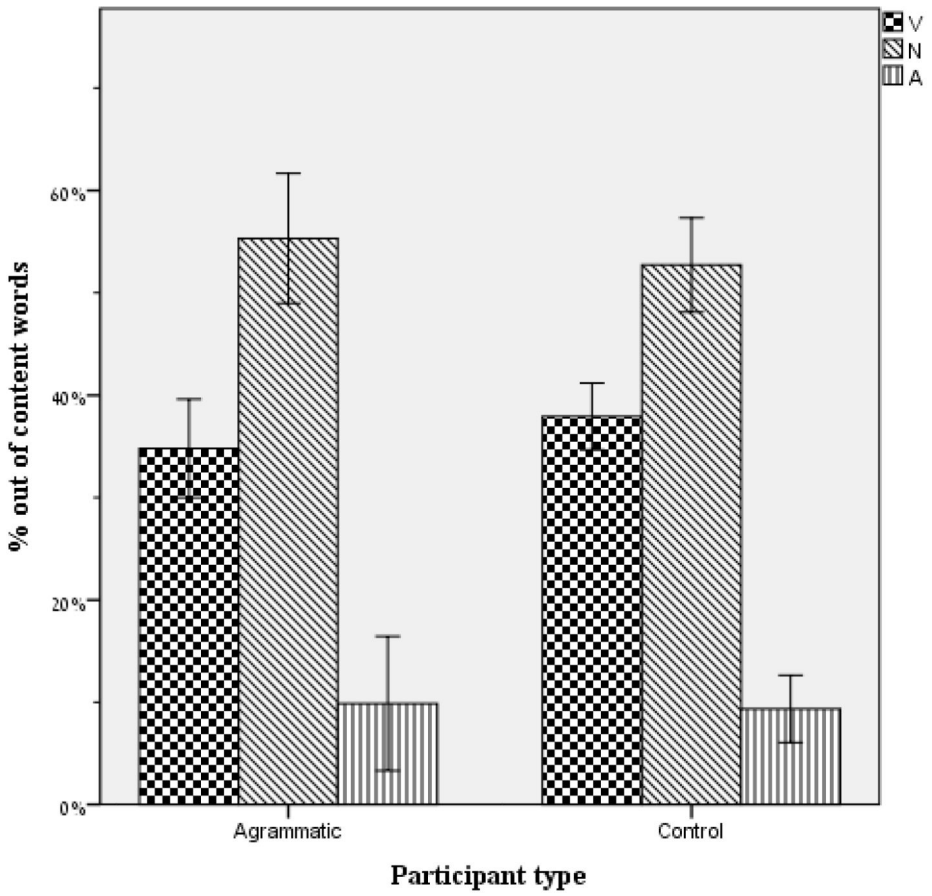

Figure 2.

percent of words from different grammatical categories - adjectives (A), verbs (V) and nouns (N) - out of total content words in the agrammatic and control groups

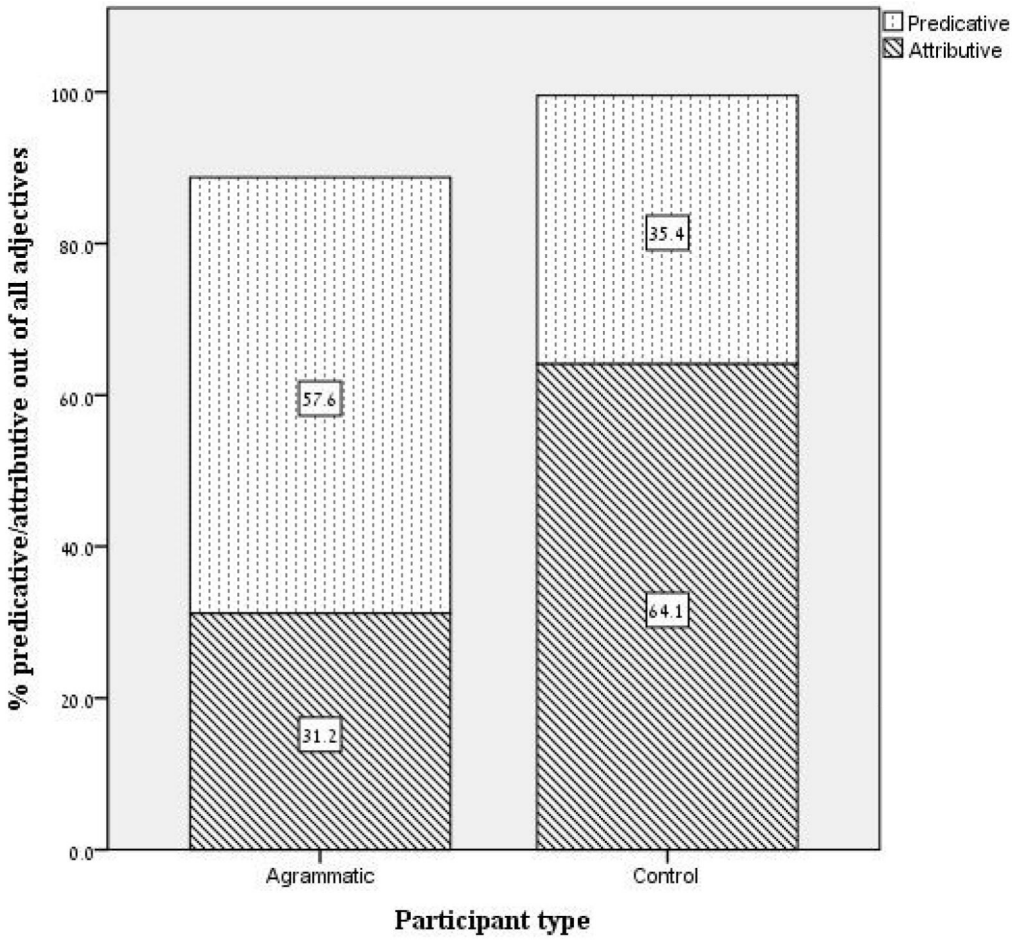

Figure 3.

Percentage of predicative and attributive adjectives out of all adjectives in agrammatic and control participants (columns do not add up to 100% because of unclassifiable adjectives)

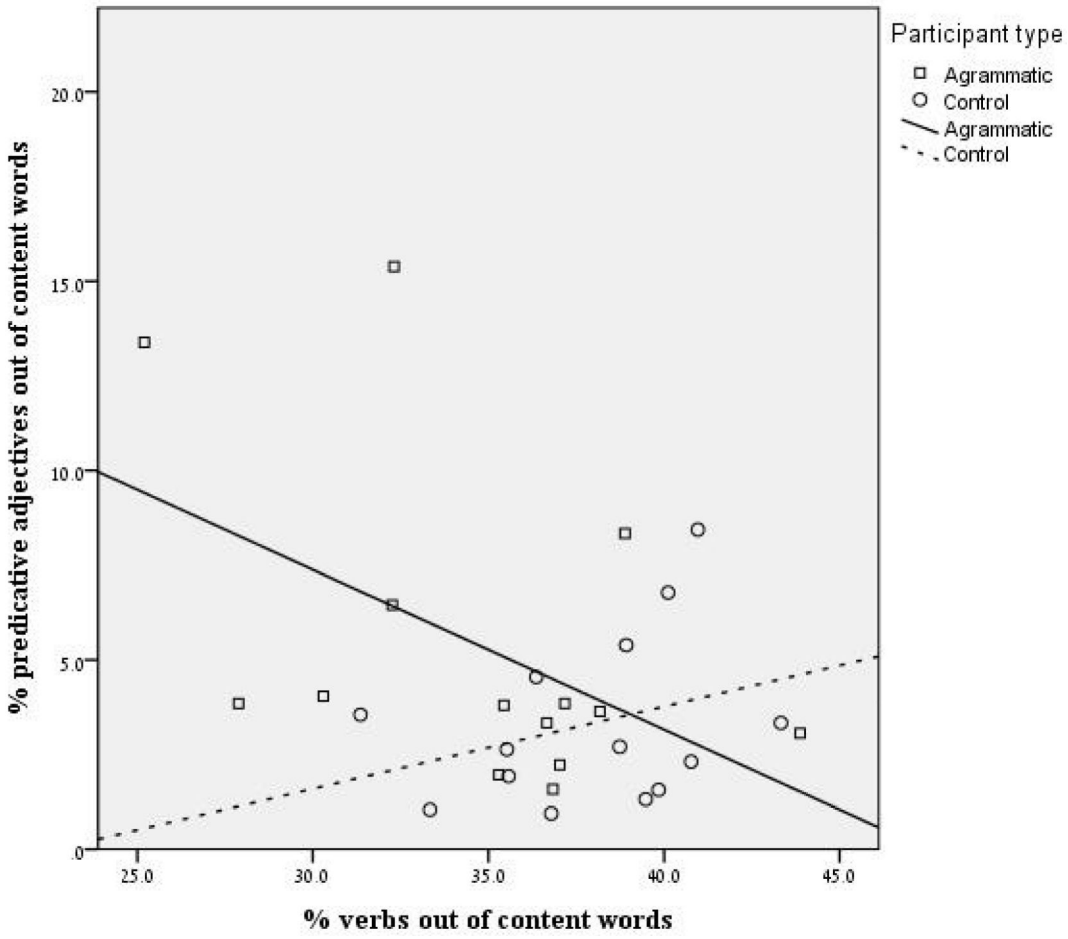

Figure 4.

Correlation between proportion of verbs and proportion of predicative adjectives in the agrammatic and control groups

Table 1

Agrammatic participants' language test scores

Participant	WAB-AQ	% grammatical sentences	NNB nouns % correct	% correct verb naming (average of NNB and NAVS VNT
1	71.2	11.5	75	64.8
2	75.8	62.2	94	91
3	69.7	9.1	94	65.5
4	82.7	24.2	100	100
5	71.9	61.3	94	74.5
6	65.9	87.0	81.25	58.2
7	85.4	29.2	100	97
8	73.0	30.4	94	90
9	77.6	64.3	93.75	84.7
10	82.5	78.6	100	72.5
11	78.1	18.7	94	92.5
12	68.1	41.2	62	55.5
13	80.0	63.4	100	65.9
14	85.4	75	--	73
Mean (SD)	76.2 (6.4)	42.6 (30.7)	90.9 (11.4)	77.5 (14.8)

Note: WAB-AQ = Western Aphasia Battery Aphasia Quotient; NNB = Northwestern Naming Battery; NAVS VNT = Northwestern Assessment of Verbs and Sentences, Verb Naming Test

Table 2

Lesion characteristics for agrammatic participants

Participant	Lesion localization
1	Pars triangularis and pars orbitalis of the IFG and prefrontal cortex, extending to the primary somatosensory cortex, and including anterior MTG and STG
3	Supramarginal and angular gyri extending to the fusiform gyrus, as well as pars operacularis of the IFG and the premotor cortex
4	Pars triangularis and pars orbitalis of the IFG, dorsolateral prefrontal cortex, pre- and postcentral gyurs, and extending to the rostral part of the MTG and STG
5	Pars orbitalis and pars opercularis of the IFG, anterior MTG and STG, extending to subcortical regions
6	Pars opercularis, premotor cortex, inferior precentral and postcentral gyri, extending to the anterior temporal lobe
7	Frontal, temporal, and parietal regions
8	Posterior lesion, including portions of the inferior, middle and superior temporal gyri, and pars opercularis
9	Inferior frontal and prefrontal gyri, extending to the anterior MTG and STG
11	Massive infarction involving the entire distribution of the left anterior and middle cerebral arteries; some sparing of posterior temporal lobe
12	Posterior regions, in particular the STG, supramarignal gyrus, and superior parietal lobule, and encompassing a small portion of tissue in the IFG
13	Pars orbitalis of the IFG, STG and MTG, extending to the fusiform gyrus

Note: IFG = inferior frontal gyrus; MTG = middle temporal gyrus; STG = superior temporal gyrus

Table 3

Production of content words by grammatical category (number (proportion)) and adjective types by participant group

Participant	Verbs (%)	Nouns (%)	Adj. (%)	Total Content Words	N:V	Pred. Adj (% of Adj)	Attr. Adj (% of Adj)
Agrammatic							
1	28 (35.4)	45 (57.0)	6 (7.6)	79	1.61	3 (50.0)	0 (0.0)
2	32 (25.2)	66 (52.0)	29 (22.8)	127	2.06	17 (58.6)	9 (31.0)
3	18 (35.3)	29 (56.9)	4 (7.8)	51	1.61	1 (25.0)	2 (50.0)
4	44 (36.7)	71 (59.2)	5 (4.2)	120	1.61	4 (80.0)	1 (20.0)
5	43 (43.9)	47 (48.0)	8 (8.2)	98	1.09	3 (37.5)	4 (50.0)
6	20 (32.3)	38 (61.3)	4 (6.5)	62	1.9	4 (100.0)	0 (0.0)
7	29 (37.2)	46 (59.0)	3 (3.9)	78	1.59	3 (100.0)	0 (0.0)
8	29 (27.9)	66 (63.5)	9 (8.7)	104	2.28	4 (44.4)	3 (33.3)
9	14 (38.9)	19 (52.8)	3 (8.3)	36	1.36	3 (100.0)	0 (0.0)
10	21 (38.2)	25 (45.5)	9 (16.4)	55	1.19	2 (22.2)	7 (77.8)
11	50 (37.0)	77 (57.0)	8 (5.9)	135	1.54	3 (37.5)	3 (37.5)
12	21 (32.3)	28 (43.1)	16 (24.6)	65	1.33	10 (62.5)	4 (25.0)
13	70 (36.8)	106 (55.8)	14 (7.4)	190	1.51	3 (21.4)	11 (78.6)
14	30 (30.3)	63 (63.6)	6 (6.1)	99	2.10	4 (66.7)	2 (33.3)
Mean number (SD)	32.1 (15.1)	51.9 (24.2)	8.9 (7.0)	92.8 (41.0)	1.63 (.35)	4.6 (4.1)	3.3 (3.5)
Mean % (SD)	34.8 (4.8)	55.3 (6.4)	9.9 (6.6)			57.6 (28.6)	31.2 (26.6)
Control							
1	68 (41.0)	74 (44.6)	24 (14.5)	166	1.09	14 (58.3)	10 (41.7)
2	53 (40.8)	64 (49.2)	13 (10.0)	130	1.21	3 (23.1)	10 (76.9)
3	53 (31.4)	95 (56.2)	21 (12.4)	169	1.79	6 (28.6)	15 (71.4)
4	51 (39.8)	62 (48.4)	15 (11.7)	128	1.22	2 (13.3)	12 (80.0)
5	39 (43.3)	47 (52.2)	4 (4.4)	90	1.21	3 (75.0)	1 (25.0)
6	32 (33.3)	57 (59.4)	7 (7.3)	96	1.78	1 (14.3)	6 (85.7)
7	71 (40.1)	82 (46.3)	24 (13.6)	177	1.15	12 (50.0)	12 (50.0)
8	37 (35.6)	59 (56.7)	8 (7.7)	104	1.59	2 (25.0)	6 (75.0)
9	32 (36.4)	45 (51.1)	11 (12.5)	88	1.41	4 (36.4)	7 (63.6)
10	43 (38.7)	59 (53.1)	9 (8.1)	111	1.37	3 (33.3)	6 (66.7)
11	30 (39.5)	42 (55.3)	4 (5.3)	76	1.40	1(25.0)	3 (75.0)
12	27 (35.5)	45 (59.2)	4 (5.3)	76	1.67	2 (50.0)	2 (50.0)
13	195 (38.9)	253 (50.5)	53 (10.6)	501	1.30	27 (50.9)	26 (49.1)
14	39 (36.8)	59 (55.7)	8 (7.6)	106	1.51	1 (12.5)	7 (87.5)

Participant	Verbs (%)	Nouns (%)	Adj. (%)	Total Content Words	N:V	Pred. Adj (% of Adj)	Attr. Adj (% of Adj)
Mean number (SD)	55.0 (42.5)	74.5 (53.5)	14.6 (13.1)	144.1 (108.1)	1.41 (.23)	5.8 (7.3)	8.8 (6.4)
Mean % (SD)	37.9 (3.3)	52.7 (4.6)	9.3 (3.3)			35.4 (18.9)	64.1 (18.4)

Note: Pred adj = predicative adjective; Attr adj = attributive adjective. Percentages of adjective types do not necessarily add up to 100% because of unclassifiable adjectives