Verb Argument Structure in Narrative Speech: Mining AphasiaBank

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ABSTRACT

Previous research has found that verb argument structure characteristics (such as the number of participant roles in the situation described by the verb) can facilitate or hinder aphasic language production and comprehension in constrained laboratory tasks. This research needs to be complemented by studies of narrative or unrestricted speech, which can capture the spontaneous selection of verbs and grammatical structures by people with aphasia and may be particularly sensitive to the relative cost of access to different verb types in more natural conditions. Focusing on the number of subcategorization options, we investigated verb argument structure effects in a large sample of narratives from AphasiaBank, by speakers with aphasia, as well as control speakers without brain damage. Verb argument structure complexity did not negatively affect verb selection in any type of aphasia. However, people with aphasia, particularly with Broca's aphasia, used verbs in less complex and diverse ways, with fewer arguments and less diverse subcategorization options. In line with previous research, this suggests that deficits in verb use in aphasia are likely due to difficulties with the online application of or partial damage to verb argument structure knowledge.

KEYWORDS: Verb argument structure, aphasia, subcategorization options, spontaneous speech in aphasia, verb processing in aphasia

Learning Outcomes: As a result of this activity, the reader will be able to (1) discuss the concept of verb argument structure and how verb access versus verb use can be measured in aphasia; (2) discuss evidence

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suggesting that verb representations are at least partially preserved in aphasia, while the use of verbs is compromised; and (3) describe differences in patterns of verb use between healthy adults, those with aphasia, and those with subtypes of aphasia.

People with aphasia (PWA), especially speakers with agrammatic aphasia, are known to have difficulties with verb processing that largely underlie impaired production and comprehension of sentence structure.[1–3] To develop optimal approaches for treating verb and sentence processing deficits, it is crucial to know whether there are impairments in access to verb representations (i.e., PWA cannot produce certain verbs) or whether there is a reduced ability to use verbs effectively in sentence processing while access to verb representations is preserved (i.e., PWA do produce approximately the same verbs as neurologically healthy speakers but use them in incorrect or simpler ways).

Experimental evidence seems to suggest that the second alternative may be true at least for speakers with agrammatic aphasia. Several behavioral and eye-tracking studies of naming and sentence production show that people with agrammatic aphasia manifest the same effects of complexity of verb argument structure (VAS; see **Appendix A** for definitions) as healthy speakers, demonstrating greater difficulty with verbs that have a greater number of arguments.[4–6] Along the same lines, an eye-tracking study by Mack and colleagues showed that VAS information was available to individuals with agrammatic aphasia, and it facilitated integration of arguments in sentence comprehension.[7] These results indicate that VAS is at least to some degree preserved in speakers with agrammatic aphasia. If impaired access to or knowledge of VAS is not at the core of verb-related problems with sentence processing and production, then the deficit likely lies in how this knowledge is applied online.

Highly constrained experimental tasks such as naming, sentence completion, and sentence–picture matching allow for a high level of experimental control, so that specific variables can be uniquely manipulated. However, evidence obtained under restrictive experimental conditions has some limitations. First, results may be affected by strategies adopted by participants to manage a given experimental task. Second, constrained tasks may not capture spontaneous lexical choice by PWA, which may be subject to avoidance behaviors.[8] Thus, they provide limited information on the relative difficulty of processing different linguistic items and structures. Therefore, it is important to complement constrained language tasks with analysis of spontaneous speech to get at the core of aphasic deficits. In the particular case of verb research, laboratory experiments may show the best possible verb processing performance by PWA as enforced by task conditions, such as forced choice or the requirement to produce a prompted complex sentence structure. Studies of spontaneous speech, on the other hand, capture the spontaneous choice of verbs and grammatical structures by PWA and may be particularly sensitive to the relative cost of access to different verb types under more natural circumstances, assuming that speakers tend to avoid the use of lexical items and grammatical structures that pose a particular difficulty for them, for efficiency reasons.

Several studies have investigated VAS characteristics in spontaneous speech in aphasia (again, mostly in agrammatic speakers).[9–12] Taken together, this body of research suggests that PWA do not differ from healthy speakers in their choice of verbs in terms of argument structure, also preferring intransitive verbs to verbs with a greater number of arguments.[12] The use of verbs, on the other hand, differs between PWA and healthy speakers: even though PWA tend to use the same types of verbs, they use them in less complex ways, i.e., with a smaller number of realized arguments (for example, they may use the potentially transitive verb *to read* only in intransitive contexts—*The girl reads*—rather than transitively—*The girl reads a book*).[9,11]

A limitation of the above studies of VAS effects in spontaneous speech in aphasia is that they used small or medium-sized participant groups of 5 to 20 individuals.[10,12] Also, these studies restricted the characterization of VAS to the number of arguments (valency). Valency has been shown to affect the behavioral and neural cost of verb processing.[13–15] However, there are more VAS characteristics that contribute to verb processing cost in healthy speakers and that should therefore be investigated in aphasic speech as well, preferably in larger samples.

One understudied VAS characteristic is the verb's number of subcategorization options (SOs), that is, the number of different grammatical classes that can serve as the verb's arguments (see **Appendix A** for an example). Several behavioral experiments have shown that verbs with a greater number of SOs pose a greater processing cost to healthy individuals, even when used in the same type of syntactic structure as verbs with a lower number of SOs (though some studies did not replicate this result).[16–19] In line with this, neuroimaging studies have found increased neural activation associated with processing verbs with a greater number of SOs in healthy speakers.[20,21] However, the effect of the number of SOs in aphasia has been investigated in only a few studies. Shapiro and Levine compared alternating and nonalternating datives in sentence comprehension with a secondary task (cross-modal lexical decision).[22] They found that individuals with Broca's aphasia, just like healthy controls, did not show an effect of the number of SOs on reaction times in the secondary task, whereas a subsample of individuals with fluent aphasia seemed to slow down for verbs with a greater number of SOs.

We investigated VAS effects in a large sample of narratives from AphasiaBank,[23] a large database of discourse samples and test scores from PWA and neurologically healthy control participants. Narrative speech samples from a large group of PWA and control speakers were examined for three aspects: (1) the number and variety of verbs; (2) the type of verbs that were used (in terms of the number of SOs), and (3) how these verbs were used (in terms of the realized argument structure and type of SOs, and in terms of accuracy of inflection and VAS). The study could have several possible outcomes. One possibility is that PWA would tend to use verbs with a lower number of SOs than healthy controls. This would suggest decreased availability of more complex verb representations. By contrast, if PWA use verbs that are similar in terms of the number of SOs to those used by control speakers, there is likely no problem with the access to those verbs themselves. Furthermore, it is possible that PWA choose verbs of the same SO complexity as healthy controls, but then use these verbs in less complex structures. For example, PWA may use a smaller variety of SOs or choose less complex SOs (e.g., those involving a smaller number of arguments, or simple noun phrase arguments rather than clauses). Such outcomes would indicate that representations of even complex verbs are still available to PWA but manipulation of information contained in verb representations is compromised.

Although previous research has mostly investigated VAS effects in agrammatic aphasia (although see Edwards and Bastiaanse[10]), we included data from multiple aphasia types (Anomic, Broca's, conduction, and Wernicke's). This allowed us to test whether verb access and use patterns differ between aphasia types with more lexically based versus grammatically based deficits. Aphasia types were identified by Western Aphasia Battery-Revised (WAB-R) diagnosis, a standard reported characteristic in the AphasiaBank database. We acknowledge that diagnosis by WAB is a suboptimal characterization of PWA but it provides a helpful, if rough, standardized categorization of PWA, particularly for corpus research such as presented here. The present study did not include a specific measure by which to identify agrammatism in the aphasic participants. Instead, we assumed that the group diagnosed with Broca's aphasia by WAB-R in the AphasiaBank data set was most likely to contain speakers with agrammatism (although agrammatism is not exclusive to or necessary for that diagnosis).

METHODS

Participants

Spontaneous narratives of the Cinderella tale were obtained from AphasiaBank,[23] a large database of discourse samples and test scores from PWA and neurologically healthy control participants. Cinderella narratives were chosen because they appear to elicit longer speech samples compared with other narrative types in AphasiaBank. Data from 137 healthy control participants and 188 PWA (74 anomic, 53 Broca's, 41 conduction, 20 Wernicke's, as diagnosed based on the Western Aphasia Battery-Revised) were analyzed (see participant group data in Table 1). The control group had a slightly higher ratio of females than the aphasic groups combined (chi-square = 3.184, $p = 0.074$), but there was no significant overall difference in gender distribution between the five groups (chi-square = 3.509, $p = 0.476$). There was no difference in age between the control and the aphasic groups combined (F [1, 321] = 2.677, $p = 0.103$), but one subgroup of aphasia was younger than the control participants (F [4, 318] = 3.281, $p < 0.05$; Broca's < controls). WAB-R aphasia quotients (AQs) also differed between the aphasic groups (F [3, 183] = 116.024, $p < 0.001$; anomic > conduction > Wernicke = Broca). There was no correlation between age and WAB-R AQ ($r = -0.011$, $p = 0.879$). In accordance with the AphasiaBank inclusion criteria, all participants had aphasia due to stroke and did not have other cognitive comorbidities.

Procedure

For AphasiaBank, Cinderella narratives were elicited in the following way: participants were asked to look through a wordless picture book of Cinderella and to remember the story, then the book was taken away and participants were asked to tell the story.[24] For this study, Cinderella narratives in Codes for the Human Analysis of Transcripts (CHAT) format were extracted from AphasiaBank using Computerized Language Analysis (CLAN) programs,[24] excluding fragments of speech produced by the investigator. In case of repeated recordings per participant, we only used the first Cinderella sample. We extracted all verbs that were used in the narratives in any form (auxiliary and modal verbs were not included; verbs that can be homonymous to adjectives in certain forms, such as *to excite–exciting*, were also excluded to eliminate noise caused by errors in automated part-of-speech tagging).

Scoring

For the analysis of verb choice, all extracted verbs were coded for the number of SOs based on SOs reflected in verb entries in the online version of Longman Dictionary of Contemporary English (http://www.ldoceonline.com). For example, the verb *to chew* received a score of 3 because it can be used with three SOs: intransitively (*The dog was chewing*), transitively (*The dog was chewing a bone*), and with a prepositional phrase (*The dog was chewing on a bone*). Verbs were also coded for possibility of transitive use (binary: "transitive use not possible" versus "transitive use possible"), length in the number of phonemes, logarithm of spoken frequency,[25] and imageability.[26]

For the analysis of verb *use*, we selected a subset of verbs, because this analysis required manual coding that was not practically feasible on the full set of verbs used in all narratives. To ensure inclusion of verbs with both high and low numbers of SOs, this subset included 30 verbs with a low number of SOs (one or two SOs, such as *to ruin* or *to achieve*) and 30 verbs with a high number of SOs (four or more SOs, such as *to prepare* or *to offer*). Verbs in both groups were transitive and were matched on the logarithm of spoken frequency,[25] imageability,[26] and length

Table 1 Characteristics of Participant Groups

Group	Total *n*	Female (%)	Age (Range)	WAB-R AQ (Range)
Anomic aphasia	74	41.9	61.5 (32.7–85.2)	85.5 (63.4–95.1)
Broca's aphasia	61	41.5	57.8 (30.3–78.3)	52.8 (16.8–77.6)
Conduction aphasia	41	46.3	63.7 (30.8–90.7)	69.8 (49.0–90.0)
Wernicke's aphasia	20	40.0	66.2 (40.5–81.3)	54.4 (28.2–74.4)
Non-aphasic controls	137	52.6	63.5 (23.0–89.5)	n/a

in syllables and in phonemes (all $p > 0.10$). All occurrences of these verbs in the narratives were manually coded for inflection accuracy, number of arguments realized in the sentence, argument-number accuracy (missing or redundant arguments), argument-type accuracy (erroneous argument types), and types of SOs realized in the sentence. For example, the utterance *The prince close* was coded as having incorrect inflection (because the verb was missing an inflectional affix, such as *-ed* or *-s*), incorrect number of arguments (because the verb was missing an object, such as *close the door*), and incorrect type of argument (automatically, because of the erroneously missing argument). For the analysis of SO type, we distinguished verb use in a coarse subdivision, with only four categories (intransitive, transitive, ditransitive, and transitive with a clausal complement), as well as in a more fine-grained way, with 13 categories (see Appendix B for these sentence-type subcategorizations). Manual coding was performed by two research assistants with a background in linguistics, who first reached full consensus on a subset of the data (20 examples selected for their variety of subcategorizations), before each coding half of the data set. On a subset of 230 items that were coded by both assistants, interrater agreement was 0.965 for the 13-category analysis of SO type, on which the four-category division was based automatically.

Statistical Analysis

VERB CHOICE

For the analysis of how the number of SOs affected verb choice, we conducted a linear mixed effects analysis (lme4[27]) in R software (R Core Team[28]). The dependent variable was the frequency with which each verb in the data set was used by each participant. In building the model, we tested the following independent variables: participant group, WAB-R AQ (to control for a general effect of aphasia severity; set to 100 for the controls, to facilitate modeling), number of SOs, verb transitivity (a binary factor indicating whether the verb can be used transitively), verb stem length (in phonemes), spoken verb frequency (log), and verb imageability. Length, frequency, and imageability were added because they can be correlated with VAS characteristics and thus may confound the results if not included into the statistical model. It was of our interest to test for any interactions between group and VAS characteristics, so we included the interactions group $\times$ SOs and group $\times$ transitivity. We also tested for interactions between group and the verb characteristics length, frequency, and imageability. Random intercepts were included for participants and verbs (items). Significance of main effects and interactions was assessed through pairwise model comparisons.

VERB USE

To test for the effect of verb complexity (in terms of the number of SOs) and participant group on the accuracy and diversity of verb use, we conducted separate analyses for each outcome measure. For inflection errors, argument-number accuracy, and argument-type accuracy, we conducted binomial logistic regressions (glmer) in R. In these, we tested for effects of group, WAB-R AQ, verb length (in phonemes), spoken verb frequency (log), and verb imageability. For the analysis of the number of arguments used by different speakers, we conducted a linear mixed effects analysis (lme4) in R, as above. Note that all verbs in this subset could be used transitively (they only varied on the number of SOs). In all models, random intercepts were initially included for participants and verbs (items), but in cases where the addition of the random intercept for verbs led to the model being overparameterized and failing to converge, we removed it from the model.

For the analysis of the diversity of verb use, we first conducted chi-square analysis on the distribution of verb uses by group to test for main effects and pairwise chi-square tests to assess differences in verb use distribution between the five groups. We also calculated Shannon's H index,[29] for each participant group, both for a fine-grained subdivision of verb uses (13 categories) and for a coarser subdivision (four categories). The Shannon index quantifies the degree of entropy in a distribution (i.e., the unpredictability of its values, where more predictable distributions correspond to lower Shannon index values). The proportion of a particular verb use relative to the total number of verb uses is calculated and then multiplied by the natural logarithm of this proportion. The resulting product is summed across verb uses, and multiplied by −1. The higher the resulting value, the greater the diversity of verb use.

RESULTS

Quantity and Type/Token Ratios of Verbs

Table 2 shows the mean total number of words and the mean number of verbs used by each participant group (tokens), as well as the mean number of different verbs (types) and the type/token ratios (TTR: overall and for the verbs alone). One-way analyses of variance showed main effects of group on the total number of words (F_{Total} [1, 305] = 43.936, $p < 0.001$) and the overall TTR (F_{TTR} [1, 305] = 7.146, $p < 0.001$). The control group produced the largest number of words, and the group with Broca's aphasia produced the smallest number of words (Table 2). The overall TTR was significantly lower for controls than all aphasic groups, except speakers with Wernicke's aphasia (Table 2). Within aphasic groups, speakers with Broca's aphasia only had a higher TTR than speakers with Wernicke's aphasia, with no other group differences (Table 2).

On the three verb-related variables, one-way analyses of variance also showed main effects of group ($F_{\text{Verb-Tokens}}$ [4, 302] = 28.578, $p < 0.001$; $F_{\text{Verb-Types}}$ [4, 302] = 27.975, $p < 0.001$; $F_{\text{Verb-TTR}}$ [4, 302] = 8.619, $p < 0.001$). Bonferroni-corrected pairwise comparisons showed that speakers with Broca's aphasia patterned with the control speakers on all three verb-related measures, and the three other aphasic groups had a higher number of verb tokens and types than controls but did not differ from one another (Table 2). The controls had a higher verb TTR than speakers with anomic, conduction, and Wernicke's (but not Broca's) aphasia, with no significant differences between aphasic groups (Table 2).

Choice of Verbs

The linear mixed effects model of verb choice that fit the data optimally is presented in Table 3. The analysis revealed main effects of frequency (chi-square = 25.031, $p < 0.001$), length (chi-square = 6.829, $p < 0.01$), and an interaction between group and transitivity (chi-square = 18.956, $p < 0.05$). The interaction between group and SOs was marginally significant (chi-square = 8.016, $p = 0.091$), so we decided to include it in the final model, as this was our primary effect of interest. No other main effects or interactions approached significance (all $p > 0.2$).

To sum up the results, shorter verbs and verbs with a higher spoken frequency were used more frequently in the Cinderella narratives (note that although pairwise differences between controls and speakers with Broca's and anomic aphasia reached significance, the main

Table 2 Mean Number of Verbs and Type/Token Ratios per Participant Group

	Mean No. of Words (SD)	Mean Overall Type/Token Ratio (SD)	Mean No. of Verb Tokens (SD)	Mean No. of Verb Types (SD)	Mean Verb Type/Token Ratio (SD)
Anomic aphasia	233.74 (166.74)	0.48 (0.12)	25.28 (19.59)	14 (8.40)	0.66 (0.19)
Broca's aphasia	104.2 (77.74)	0.49 (0.13)	9.44 (9.34)	5.40 (4.80)	0.70 (0.25)
Conduction aphasia	217.03 (132.75)	0.46 (0.11)	22.34 (15.54)	12.89 (7.76)	0.64 (0.15)
Wernicke's aphasia	270.63 (170.21)	0.43 (0.10)	32.21 (20.54)	16.32 (7.83)	0.59 (0.17)
Non-aphasic controls	491.53 (264.43)	0.42 (0.08)	9.68 (6.65)	7.02 (4.41)	0.77 (0.17)

Abbreviation: SD, standard deviation.
Note: Statistically significant comparisons ($p < 0.05$) are indicated by brackets.

Table 3 Output of the Linear Mixed Effects Model of Verb Choice in Cinderella Narratives

Factor	Estimate	Standard Error	df	*t* Value
(Intercept)	1.3454	0.2327	1227.3	5.782*
Subcategorization options	−0.0820	0.0450	1221.9	−1.823
Anomic (versus controls)	−0.5302	0.2305	1840.5	−2.3*
Broca's (versus controls)	−1.0465	0.3338	2396.9	−3.136*
Conduction (versus controls)	−0.4370	0.2763	2002.7	−1.582
Wernicke's (versus controls)	−0.4921	0.3200	2170.5	−1.538
Length (phonemes)	−0.0622	0.0307	871.6	−2.024*
Spoken frequency (log)	0.1290	0.0229	492.8	5.626*
Transitivity (binary)	−0.1361	0.1377	1198.3	−0.989
Subcategorization options × anomic (versus controls)	0.1229	0.0553	1472.2	2.221*
Subcategorization options × Broca's (versus controls)	0.1008	0.0750	2126.9	1.345
Subcategorization options × conduction (versus controls)	0.0584	0.0634	1601.8	0.922
Subcategorization options × Wernicke's (versus controls)	0.1738	0.0710	2041.4	2.447*
Transitivity × anomic (versus controls)	0.0923	0.1746	2017.7	0.528
Transitivity × Broca's (versus controls)	0.7038	0.2441	2577.8	2.883*
Transitivity × conduction (versus controls)	0.2253	0.2049	2282.9	1.099
Transitivity × Wernicke's (versus controls)	−0.1647	0.2287	2518.9	−0.72

*$p < 0.05$.

effect of group did not, so these differences are not explored further here). The interaction between group and transitivity (see Fig. 1) reflects that all groups, except for speakers with Broca's aphasia, used more intransitive than transitive verbs, numerically (in healthy speakers and speakers with anomic aphasia, this preference reached significance [$p < 0.001$], and for speakers with Wernicke's aphasia, it was a trend [$p = 0.072$]). Table 3 shows that only speakers with Broca's aphasia differed significantly from controls in the number of transitive verbs used.

There was a marginal interaction between group and the number of SOs used. All groups produced verbs whose SOs ranged from 1 to 8. However, speakers with aphasia, particularly of anomic or Wernicke's type, tended to use verbs with a greater number of SOs more frequently. This result was unexpected. Although there were no interactions between group, frequency, and length, at least part of this more frequent use of verbs with higher SOs in aphasia may be due to some collinearity between frequency and length and the number of SOs. Verbs with a higher number of SOs tended to be more frequent (r [372] $= 0.541$, $p < 0.001$) and shorter (r [372] $= -0.159, p < 0.01$). Therefore, these verb characteristics likely contributed to the interaction between group and SOs.

Use of Verbs

The more detailed analysis of a subset of verbs encountered in the Cinderella samples allowed us to analyze the rate of (verb) inflection errors, as an indicator of agrammatism in aphasic speech, as well as VAS error types and diversity of verb use in terms of argument structure and SOs.

INFLECTION ERRORS

Fig. 2A shows the percentages of verb inflection errors in the five groups. The binomial logistic regression revealed an effect of group (chi-square $= 15.369$, $p < 0.05$) and WAB-R AQ (chi-square $= 5.912$, $p < 0.05$), but no added effect of WAB-R AQ to that of group (chi-square $= 0.553$, $p = 0.457$). No other factors improved the model fit (all $p > 0.2$). Pairwise comparisons (through releveling of the model) showed that the control group made fewer inflection errors than all aphasic groups (all $p < 0.05$) and speakers with Broca's aphasia produced more inflection errors than all others (all $p < 0.05$), except for speakers with Wernicke's aphasia ($p = 0.16$).

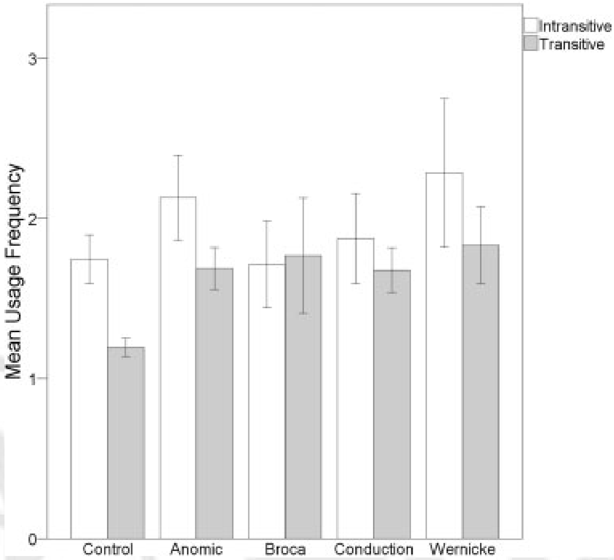

Figure 1 Frequency of usage of intransitive and transitive verbs per participant group. Error bars represent 2 standard errors of the mean (pooled over participants per group).

ARGUMENT-NUMBER ERRORS

Fig. 2B illustrates the percentages of errors in the number of arguments used (i.e., missing obligatory arguments, or erroneously added arguments). These errors were infrequent (all groups < 10%), and although the control speakers made numerically fewer such errors, there was no main effect

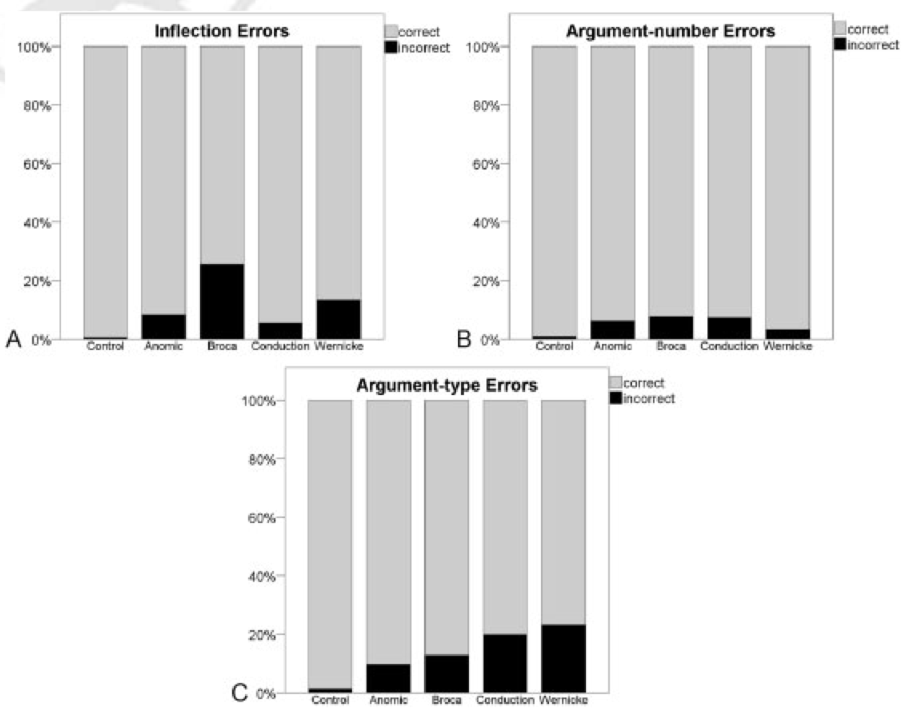

Figure 2 (A) Percentages of inflection errors per participant group. (B) Percentages of argument-number errors per participant group. (C) Percentages of argument-type errors per participant group.

of group, nor any other significant main effects.

ARGUMENT-TYPE ERRORS

Fig. 2C illustrates the percentages of errors in argument type (such as using a clausal complement where only a noun phrase is appropriate, among others). The binomial logistic regression revealed an effect of group (chi-square = 32.591, $p < 0.05$) and of WAB-R AQ (chi-square = 18.644, $p < 0.05$), but no added effect or interaction. Pairwise comparisons showed that the control speakers made significantly fewer argument-type errors than the four aphasic groups (all $p < 0.001$), with no differences between those groups.

NUMBER OF ARGUMENTS USED

Fig. 3A shows the mean number of arguments used by participant groups. The linear mixed effects analysis revealed a main effect of group (chi-square = 12.102, $p < 0.05$), with no added effect of WAB-R AQ (chi-square = 0.329, $p = 0.566$). Pairwise comparisons showed that control speakers used more arguments than speakers with Wernicke's, Broca's, and conduction aphasia. Among aphasic groups, speakers with anomic aphasia used more arguments than the other three groups, with no other significant differences. Adding imageability improved the model fit (chi-square = 5.2844, $p < 0.05$; verbs with higher imageability were used with fewer arguments), but there were no other effects (all $p > 0.2$).

DIVERSITY OF VERB USE IN SENTENCE CONSTRUCTIONS

Fig. 3B and C illustrate the diversity of verb use in different groups. Across both the fine-grained and coarse analyses, Broca's group

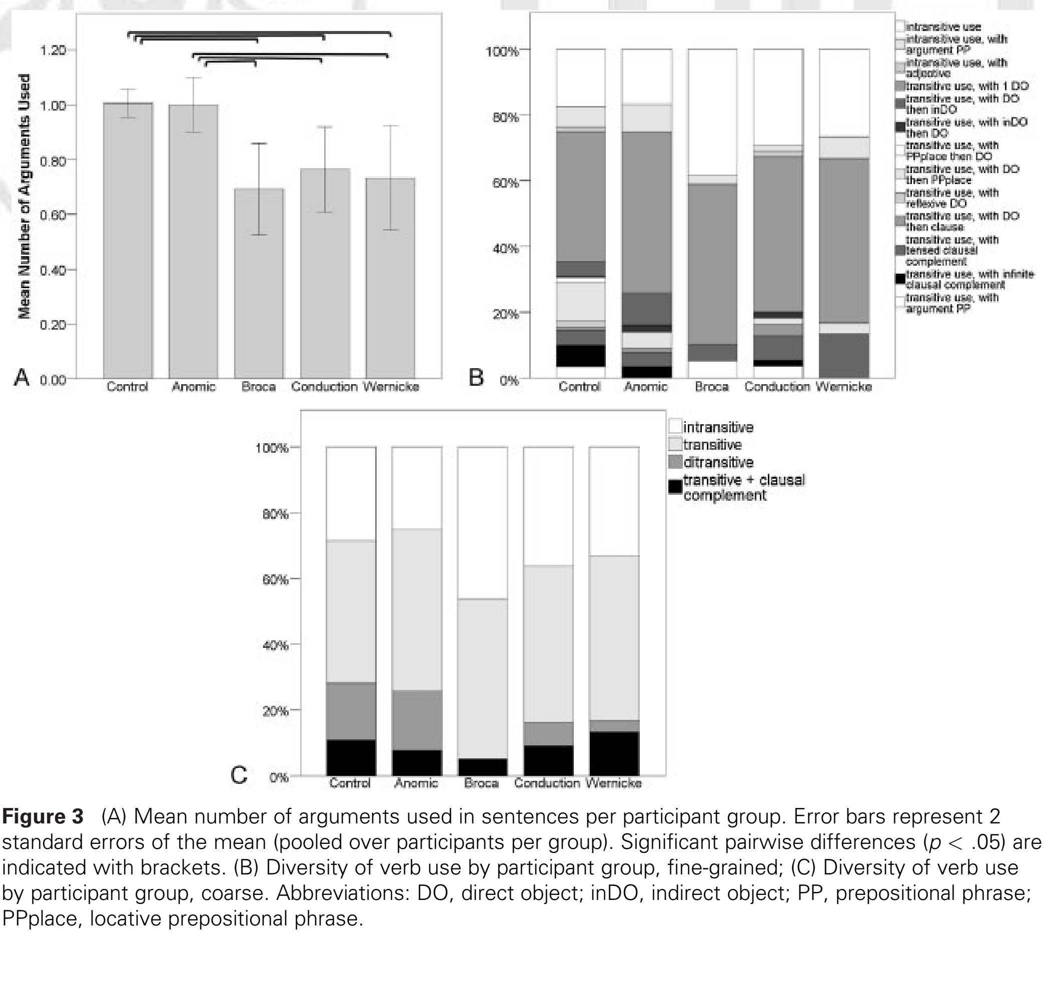

Figure 3 (A) Mean number of arguments used in sentences per participant group. Error bars represent 2 standard errors of the mean (pooled over participants per group). Significant pairwise differences ($p < .05$) are indicated with brackets. (B) Diversity of verb use by participant group, fine-grained; (C) Diversity of verb use by participant group, coarse. Abbreviations: DO, direct object; inDO, indirect object; PP, prepositional phrase; PPplace, locative prepositional phrase.

Table 4 Shannon's H Index Values on Diversity of Verb Use

	Fine-Grained	Coarse
Anomic	1.74	2.34
Broca	1.24	1.61
Conduction	1.63	2.18
Wernicke	1.58	1.82
Non-aphasic controls	1.83	2.79

used verbs less diversely compared with control and anomic groups (all chi-square > 11, $p < 0.05$). Speakers with Broca's aphasia were the only group to never use verbs ditransitively in this sample. The lower diversity of verb use in the speakers with Broca's aphasia was further reflected in the lowest Shannon H diversity index values for this group (see Table 4), used here as a descriptive measure. Furthermore, in the fine-grained analysis, the distribution of verb use was different in the control group versus speakers with anomic (chi-square $= 32.225$, $p < 0.05$) and conduction (chi-square $= 22.388$, $p < 0.05$) aphasia, as well as between speakers with anomic versus conduction (chi-square $= 21.845$, $p < 0.05$) and those with Broca's aphasia (chi-square $= 24.026$, $p < 0.05$).

DISCUSSION

The present study investigated the effects of VAS in narrative speech by speakers with aphasia and control speakers without brain damage, based on the AphasiaBank data set of Cinderella narratives. Specifically, we focused on the number of SOs, a VAS parameter that has not received much attention in aphasia research. We analyzed both the spontaneous selection and use of verbs by speakers with different types of aphasia, aiming to investigate whether access to verbs with complex VAS and/or the use of complex VAS may be impaired in these speakers.

PWA were not very different from control participants in some aspects of their verb choice: all speakers showed a preference for shorter and more lexically frequent verbs. This is consistent with previous literature on the effects of word length and frequency in aphasia.[30,31] Control speakers without aphasia, however, did have a higher TTR of verbs than speakers with anomic, conduction, and Wernicke's aphasia, who showed higher numbers of both verb tokens and types, and speakers with Broca's aphasia patterned with the control group. Although we did not test for noun use here, it is possible that speakers with anomic, conduction, or Wernicke's aphasia compensate for noun retrieval problems by overusing verbs.

There were two findings with regard to the influence of VAS parameters on verb choice. First, speakers with Broca's aphasia differed from control participants and from all other aphasia groups in that they used an equal number of intransitive and transitive verbs, whereas the other groups, including the control speakers, generally selected relatively more intransitive than transitive verbs. This finding was unexpected, because transitive verbs have a more complex VAS representation (containing a greater number of arguments) and thus should present a greater challenge than intransitive verbs,[32] particularly for PWA with agrammatism who are noted for having problems with verbs. One explanation for the relatively less frequent choice of intransitive verbs by individuals with Broca's aphasia may be that unaccusative intransitive verbs (i.e., verbs that have a passive/patientive subject [*to die*, *to fall*, *to sneeze*] as opposed to unergative intransitive verbs that have an active/agentive subject [*to talk, to skate*]) present a challenge to this group, because such verbs involve syntactic movement of the internal argument, according to the unaccusativity hypothesis.[33,34] An alternative account might be that transitive verbs have a greater number of connections to potential arguments in the mental lexicon, which facilitates lexical access. In that case, however, it remains unclear why the facilitatory effect of transitivity would only be present in Broca's aphasia. Rather, it seems that verb transitivity itself simply does not affect the verb selection of speakers with Broca's aphasia in relatively unrestricted narrative speech, in contrast to verb selection by control speakers and other PWA, particularly those with anomia or Wernicke's aphasia. This is reminiscent of and parallel to the results of Shapiro and Levine,[22] who showed the absence of an effect of SOs on verb retrieval in Broca's aphasia.

The second finding relevant to effects of VAS on verb selection in aphasia is that the study found no evidence of speakers with Broca's (or any other type of) aphasia selecting verbs with a lower number of SOs. Instead, speakers with anomic and Wernicke's aphasia somewhat more frequently used verbs with a greater number of SOs than other participant groups. Like the effect of transitivity, this effect was not in the expected direction. Previous research mostly showed that verbs with a greater number of SOs present greater difficulty, both for healthy speakers and for PWA (except perhaps for Broca's aphasia),[16,17,20–22] presumably due to more effortful access to verbs with more complex VAS representations. However, our results suggest that more complex VAS representations may actually facilitate verb access in spontaneous speech in Wernicke's and anomic aphasia. The more frequent use of verbs with a greater number of SOs by these speakers could be partly driven by correlations between the number of SOs, verb length, and frequency, but the statistical model included these two variables so they should not fully account for the effects of the number of SOs. Thus, we think verbs with a higher number of SOs may be used more frequently because they are part of a richer lexical and syntactic network, yielding additional lexical access routes.[18,32] This account is consistent with the fact that the preference for verbs with complex VAS was strongest in anomic and Wernicke's aphasia, which are characterized by compromised lexical access to a greater extent than Broca's and conduction aphasia.

The number of SOs had no effect on the grammaticality of verb use: rates of inflection errors, argument-number errors, and argument-type errors were similar for verbs with a lower and higher number of SOs. Thus, we did not find evidence that the greater number of SOs placed an additional load on lexical retrieval and thus left fewer resources available for integrating the verb into the sentence, as would have been predicted by a division-of-labor hypothesis or any account emphasizing the role of computational load on qualitative aspects of agrammatic errors.[35,36] As anticipated, the speakers with Broca's aphasia had particular difficulty with grammatical morphology, reflected in a greater number of verb inflection errors that they produce across the board. Errors that involve inappropriate argument types, however, were made more frequently by all PWA compared with control speakers.

Although PWA selected verbs of equal or greater VAS complexity than control speakers, our analysis of the verb subset showed that they used these same verbs in less complex VAS constructions. With the exception of speakers with anomic aphasia, PWA used fewer verb arguments and, particularly in case of Broca's aphasia, utilized less diverse VAS constructions than control speakers. This is in line with earlier findings generally suggesting that PWA can access verbs with a higher valency but use them with a lower number of arguments than control speakers.[9,11]

All these results together indicate that verb-related problems in speakers with Broca's aphasia (and other PWA) are not caused by impaired access to verbs themselves, but rather by impaired use of the representational options offered by verbs and their argument structure. A tentative account for the absence of transitivity effects in the spontaneous verb selection of speakers with Broca's aphasia, as well as for the lower diversity in their use of SOs, may actually be that these speakers access verb forms without the automatically associated VAS characteristics. Thus, the "weight" or complexity of VAS characteristics does not hinder verb production in speakers with Broca's aphasia, but the more diverse VAS information is not available to them for efficient and full use in sentence (de)construction. This partial-access hypothesis is worth further exploration in controlled experimental work, which might also test whether we are in fact dealing with partial damage to lexical (VAS) representations.

The present study complements previous experimental research on VAS by providing information on spontaneous lexical and grammatical choices by PWA. AphasiaBank proved a very effective source for analysis of spontaneous speech by PWA, because it contains a large data set and allows investigators to perform many stages of analysis automatically. We used only one spontaneous speech type out of those available in AphasiaBank (Cinderella narrative). Future research can attempt to compare effects of VAS across different discourse types, such as maximally unrestricted discourse types, procedural discourse, picture descriptions, conversation, and so on. Such research would demonstrate if any discourse types are more sensitive to impaired VAS access/use than others. Extrasensitive elicitation methods would be an optimal choice for diagnosing VAS impairments based on spontaneous speech. Such research may also show which discourse types tend to elicit verbs with more complex VAS and thus have a potential to be used in language therapy targeting verb impairments.

The present study suggests that to determine treatment goals, discourse samples by PWA should be assessed both for verb access (i.e., the overall number and TTR of verbs and whether verbs with potentially complex VAS are used at all) and for verb use (i.e., whether verbs are used with complex and diverse VAS and, particularly, SO options or only with the simplest options). In the first case, treatment would initially target verb retrieval.[37–39] In the second and more likely case, treatment would more specifically train verb use in sentence context, including practicing the use of correct VAS, diverse arguments, and correct inflection.[32,41,42] Several agrammatism treatments have emphasized treating verbs with more complex VAS (e.g., a greater number of arguments) to obtain generalized improvement of verb and sentence processing.[32] Our findings indicate that the potential number of SOs itself does not affect performance in terms of verb retrieval or inflection in sentence contexts. However, regardless of how treated verbs are selected (e.g., based on functional relevance), treatment should address verb use in diverse lexical and grammatical contexts,[40,41] and for that reason it is indeed necessary to select verbs with multiple SOs, as only these allow for such variety. Diversity in the use of verb SOs may be an underestimated distinguishing feature in the spontaneous speech production by neurologically healthy speakers and PWA, particularly speakers with agrammatism. Large data sets, such as AphasiaBank, can be mined successfully for different types of verb use in relatively unconstrained speech.

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Appendix A Definitions of Major Terms Describing Verb Argument Structure

Argument—participant of a situation described by the verb. For example, the verb *to read* has two arguments (*The girl reads a book*) and the verb *to cough* has one argument (*The girl coughed*).

Intransitive use—using a verb with one argument (*The girl is reading*).

Subcategorization option—type of grammatical constituent(s) that can be used with a verb. For example, the verb *to complete* has only one SO (it can only be followed by a noun phrase [*He completed the task*]), whereas the verb *to demand* has more than one SO (it can be followed by a noun phrase [*He demanded a refund*] or a clause [*He demanded that they leave*], or an infinitive phrase [*He demanded to see them*]).

Transitive use—using a verb with two arguments (*The girl reads a book*).

Verb argument structure—information about possible arguments of the verb (about their number, possible meanings, possible grammatical characteristics, and so on).

Appendix B Sentence Type Subcategorizations for Assessment of Diversity of Verb Use

Example	Fine-Grained Verb-Use Subcategorization	Coarse Verb-Use Subcategorization
The girl is talking.	Intransitive use	Intransitive
The girl is talking to her mother.	Intransitive use, with argument PP	
Her voice sounded familiar.	Intransitive use, with adjective	
The girl read a book.	Transitive use, with 1 DO	Transitive
The sisters love themselves.	Transitive use, with reflexive DO	
He brought into his home a woman.	Transitive use, with PPplace then DO	
She forgot about it.	Transitive use, with argument PP	
The girl sent her mother a letter.	Transitive use, with inDO then DO	Ditransitive
The girl sent a letter to her mother.	Transitive use, with DO then inDO	
The mother sent her daughter to college.	Transitive use, with DO then PPplace	
The girl told her mother that she was ready to leave.	Transitive use, with DO then clause	
The girl remembered that she had been in this area before.	Transitive use, with tensed clausal complement	Transitive, with clausal complement
The girl remembered to bring her coat.	Transitive use, with infinite clausal complement	

Abbreviations: DO, direct object; inDO, indirect object; PP, prepositional phrase; PPplace, locative prepositional phrase.