ABSTRACT

Title of thesis: EXPLORING THE RELATIONSHIP BETWEEN VERB RETRIEVAL, AGRAMMATISM AND PAUSES

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Persons with agrammatic aphasia (a symptom of Broca's aphasia) tend to speak at a slow rate compared to neurotypical adults and to other aphasia subtypes (Kertesz, 2007). This connection between slow rate and agrammatic aphasia is underexplored. This study examines three key variables impacting speech rate in agrammatic narratives: syntactic impairment (i.e., diagnosis of agrammatism), verb retrieval, and pauses. Specifically, forty-five narrative (Cinderella) samples (15 agrammatic aphasia, 15 anomic aphasia, and 15 controls) from AphasiaBank database (MacWinney et al., 2011) were converted into Praat TextGrids (Boersma & Weenink, 2023) with sound files, and the first five qualifying pre-verb pause durations were recorded. Additionally, the first five qualifiying pre-noun pauses were logged for comparison as well as the overall grammaticality of each targeted utterance. The results were that the number of pauses and pause duration differentiated persons with agrammatic aphasia from persons with anomic aphasia and neurotypical controls, yet verb retrieval and the syntactic well-formedness of an utterance did not significantly vary by aphasia type in utterances where verbs were successfully retrieved. Overall, this study did not lend support to the Synergistic Processing Bottleneck model for agrammatic aphasia (Faroqi-Shah, 2023).

EXPLORING THE RELATIONSHIP BETWEEN VERB RETRIEVAL, AGRAMMATISM AND PAUSES

by

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Exploring the Relationship Between Verb Retrieval, Agrammatism, and Pauses

Persons with agrammatic aphasia (a symptom of Broca's aphasia) tend to speak at a slow rate compared to neurotypical adults and to other aphasia subtypes (Kertesz, 2007). Some factors contributing to slow speaking rate in agrammatic aphasia are limitations in word production, sentence comprehension, and working memory. An additional factor contributing to this slow rate is grammatical difficulties. Some recent research suggests syntactic impairment, as in challenges producing words in sequence according to grammatical conventions, is the most significant cognitive and linguistic factor contributing to nonfluency in aphasia (Nozari & Faroqi-Shah, 2017). However, this connection between slow rate and grammatical difficulties is not well understood. One possibility is that persons with agrammatic aphasia, who are persons with syntactic difficulties, pause more often than as they struggle with syntactic planning, as in when words are put in the correct order to create a coherent message. In general, agrammatic speech consists mostly of content words (particularly nouns) and limited function words and inflections (Speer & Wilshire, 2013). Verb deficits have also been associated with agrammatism (Miceli et al., 1984; Zingeser & Berndt, 1990; Kim & Thompson, 2000). Thus, another possibility is that agrammatic speakers pause more frequently as they struggle with retrieval of verbs and function words.

Given that this link between syntactic impairments and slow rate of speech has not been sufficiently explored, this project will examine the connection among three variables in narrative speech: syntactic impairment (i.e., diagnosis of agrammatism), verb retrieval, and pauses. The following sections review research related to each of these variables, ultimately suggesting that a fine-grained analysis of pauses and verb retrieval at the utterance level may yield important insights into the nature of agrammatism.

Verb Retrieval and Agrammatism

One factor contributing to the relationship between syntactic impairment and slow rate of speech could be verb retrieval. Verbs are a central component of sentence[1] production as each sentence requires at least one verb. Consequently, verbs have been investigated as a source of syntactic deficits in agrammatism.

Many studies have found that persons with agrammatic aphasia are less successful on verb retrieval and posit varied explanations for these findings (Crepaldi et al., 2011; Lee & Thompson, 2004; Zingeser & Berndt, 1990). One proposition is that grammatically correct use of verbs is complex, especially when compared to grammatically correct use of nouns. First, effective verb use requires at least one argument – as in a component that serves to complete the meaning of a verb. In a sentence such as ‘Lynn eats,’ there is one argument (Lynn) for the verb (eats). Verbs with more complex argument structures, as in verbs with multiple arguments, have been demonstrated to be less commonly produced by those with agrammatic aphasia (Lee & Thompson, 2004). Nouns, by contrast, typically possess far fewer syntactic constraints. Second, in many languages, verb production may be more difficult than noun production because verb use necessitates more morphosyntactic transformations based on verb tense (and aspect, mood, etc. depending on the language) whereas nouns typically have fewer inflectional varieties (Zhang & Hinzen, 2022). Zhang & Hinzen (2022) found a significant lack of tense marking in persons with Broca’s aphasia relative to non-brain damaged controls. Returning to the example of ‘Lynn eats,’ the infinitive verb, ‘to eat,’ was converted into grammatically acceptable third-person singular present tense form by adding the bound morpheme ‘s.’ Failure to add the ‘s’ morpheme to the root, or the addition of a grammatically invalid morpheme (such as -ed), would harm

[1] A sentence, as opposed to an utterance, is commonly the unit of interest in this area of research. Consequently, this literature review will include research focusing on sentences in addition to research focusing on utterances.

comprehensibility. A third factor that makes verbs more difficult to produce is that they may be less imageable than nouns (Bird, Howard & Franklin, 2000; Matzig et al., 2009). In both their meta-analysis of 38 papers published between 1984 and 2005 as well as their own study, Matzig et al. (2009) found that both neurotypical adults and persons with aphasia were slower and less accurate at naming actions (e.g., washing) as opposed to objects (e.g., hammer).

Numerous studies have examined picture naming in agrammatic versus anomic persons with aphasia (Matzig et al., 2009; Miceli et al., 1984; Zingeser & Berndt, 1990). Anomic aphasia is commonly understood as a mild form of aphasia characterized by challenges with word finding (Kertesz, 2006). There are questions about if word-finding challenges for persons with anomic or agrammatic aphasias vary depending on the part of speech to be retrieved. Some studies have found between group differences in verb retrieval, with persons with agrammatic aphasia performing better at noun retrieval and persons with anomic aphasia performing better at verb retrieval (Miceli et al., 1984; Zingeser & Berndt, 1990). Zingeser & Berndt (1990) found that persons with agrammatic aphasia produced fewer verbs than nouns during a word retrieval task as well as produced many more nouns than verbs during a story narration task as compared to persons with other aphasias as well as neurotypical controls. Nevertheless, most picture naming studies have found that verb retrieval deficits are not restricted to agrammatism (Bastiaanse & Jonkers, 1998; Berndt et al., 1997; Matzig et al., 2009). Although some of these studies lacked a neurotypical control group, some of these studies did include one as a point of comparison.

One inherent problem with comparing picture-naming across diagnostic groups is that this evidence has been strictly correlational. These studies investigate the relationship between aphasia type and successful verb retrieval but have not come close to identifying a causal relationship between syntactic difficulties and verb retrieval. Instead, these studies can only demonstrate associations between these variables that could be mediated by other factors, such as the sample's demographic composition or aphasia severity.

Another problem with picture-naming methods is that they test single-word, noun-versus-verb retrieval. These studies do not test verb retrieval in the context of sentence production. Language demands are different for retrieving verb picture names in isolation versus using verbs to build a sentence/grammatical utterance, with the latter being a core deficit in agrammatism.

Some research suggests that verb retrieval difficulties in connected speech tasks (e.g. spontaneous speech, narrative speech) are less severe than verb retrieval difficulties in picture-naming tasks (Pashek & Tompkins, 2002; Mayer & Murray, 2003). In these studies, both controls and aphasic patients had less difficulty, or shorter pauses, with verb finding (as well as noun finding) in narratives as compared to picture-naming or confrontation naming tasks. One prevailing explanation for these verb-finding improvements is that semantic, syntactic, or phonologic factors within or across utterances may facilitate retrieval (Pashek & Thompson, 2002). Given that much functional speech is connected, research studies assessing connected speech may better represent real-world language usage conditions.

Verb retrieval in connected speech, specifically narrative language, enables us to examine verb retrieval in the context of sentence production, thus providing stronger linking evidence between these two linguistic abilities. Two such studies found an association between verb retrieval and sentence production (Thorne & Faroqi-Shah, 2016, see also path analysis in Nozari & Faroqi-Shah, 2017), while another study did not find any consistent relationship between verb retrieval and Broca's aphasia (Broca's can be used as proxy for agrammatism, Malyutina & Zelenkova, 2020). In the Faroqi-Shah studies, some sort of verb measure was compared/correlated with some sort of sentence measure for the entire narrative. For example, in their path model of nonfluency in aphasia, Nozari & Faroqi-Shah (2017) selected the overall percentage of verbs out of total words in Cinderella story retells as one manifest variable for syntactic (or sentence) production. This approach does not address how verb retrieval may related to the production of a well-formed sentence. A more fine-grained and direct test of verb retrieval and its influence on sentence production would be to analyze verb retrieval, grammaticality, and sentence production at the instance of each sentence. Doing so will help assess if a causal relationship exists between verb production and sentences in agrammatism.

Disfluencies and Agrammatism

Language fluency is typically expressed as speech rate (or words per minute) in aphasiology (e.g., Nozari & Faroqi-Shah, 2018). Another metric of fluency is the occurrence of disfluencies (Lynch, Faroqi-Shah, Bernstein Ratner, 2022; Lynch, 2022). For this reason, disfluency can be used to better understand language planning in aphasia. Although studies of disfluencies and language planning at the utterance level have been conducted in other populations (e.g., children and adults who stutter), disfluencies have been understudied at the utterance level in an aphasia context. In the first large scale study of disfluencies in narrative speech, Lynch (2022) investigated the relationship between an aphasic person's dominant deficits (i.e., either lexical [anomic] or syntactic [agrammatic]) and frequency, location and type of disfluencies produced in Cinderella story retells. The disfluency types included in that study were extensive: prolongations, broken words, blocks, part-word repetitions, whole-word repetitions, phrase repetitions, pauses, word revisions, and phrase revisions. Transcripts of the persons with aphasia (n=161) and neurotypical participants (n=164) were analyzed in CLAN (MacWhinney, 2000) based on measures of utterance length (e.g. mean length of utterance, MLU), lexical diversity (e.g. vocabulary diversity, VOCD) and syntactic ability (e.g. developmental sentence score, DSS). Results were that overall, persons with more syntactic deficits (or more agrammatic deficits) produce more disfluencies than those with more semantic or lexical deficits. That is, disfluencies were not facilitative in language planning, as would be indicated by an inverse relationship between the proportion of disfluencies and measures of lexical diversity and syntactic ability. However, this study only derived measures for the whole narratives – i.e., a participant's total number of disfluencies and overall lexical and syntactic measures of the narrative. This type of study could be complimented by a fine-grained analysis at the exact juncture of a disfluency as that will allow for a more detailed understanding of syntactic planning difficulties in agrammatism. The present study uses this approach by examining disfluencies and utterance grammaticality within an utterance.

Pauses and Agrammatism

One disfluency type meriting special attention in slow speech rate are pauses. Initially, pauses were thought to be solely related to word-finding hesitations (Goldman-Eisler, 1958; Maclay & Osgood, 1959). That perspective evolved into pauses being thought to precede not only single words but also syntactic (structural) units longer than a word, such as clauses (Boomer, 1965; Clark & Fox Tree, 2002; Henderson et al., 1966; Rochester, 1973). Subsequent research contended that pauses reflect lexical and syntactic considerations as well as cognitive, social, and affective variables (Rochester, 1973).

This early research also started distinguishing between silent pauses (periods of silence) and filled pauses (e.g., um, uh) and how each may serve distinct language planning functions (Boomer, 1965; Rochester, 1973). Over time, silent pauses have come to be understood as either rhetorical devices or signifiers of difficulty planning or retrieving upcoming words or grammar

(MacGregor et al., 2010). In fact, silent pause duration and frequency have been positively correlated with task difficulty (MacGregor et al., 2010). As a result, silent pauses tend to precede more difficult to produce linguistic units (Rosenfield, 1987). In contrast, filled pauses are produced when the speaker is looking for information or deciding what to say next (Cossavella & Cevasco, 2021). Filled pauses can also be important automatic responses to language formulation difficulties because they indicate to the listener that the speaker intends to continue their conversational turn (Alvar et al., 2018; Clark & Fox Tree, 2002).

Pauses, both filled and silent, are relevant to this study because persons with aphasia, particularly those with agrammatic aphasia or anomic aphasia, often pause before word retrieval (Angelopoulou et al., 2018; DeDe & Salis, 2020; Sahraoui et al., 2015; Zhang & Hinzen, 2022). These pausing moments may be understood as reflecting a person with aphasia's struggle with word retrieval (Mack et al., 2015). By extension, given that this study primarily centers on verb production in aphasia, pauses prior to verbs could indicate challenges with verb retrieval.

In addition, pauses before verbs may also signal difficulty with syntactic or utterance planning. A handful of studies have explored the connection between pausing and the speed of language production in certain aphasias (DeDe & Salis, 2020; Nozari & Faroqi-Shah, 2017; Salis & DeDe, 2022; Speer & Wilshire, 2013). Salis & DeDe (2022) found in that in anomic aphasia, pause durations during Cinderella narrative retells were not associated with an utterance's syntactic complexity but instead were associated with the length of that sentence. In addition, for all groups, pauses were greater within rather than between utterances, suggesting that within-utterance pauses are more significant to examine. Crucially, this study did not include persons with agrammatic aphasia, begging the question what relationship would be found between pause frequency (and duration), sentence length, and sentence complexity if this group was included.

A recent theory of agrammatism proposes that pauses (and slow speaking rate) are inherently tied to syntactic deficits. A prevailing explanation for sentence planning and production patterns in agrammatic aphasia is the Synergistic Processing Bottleneck model (SPB) (Faroqi-Shah, 2023). According to the SPB, a combination of three linguistic processes (constituent assembly, verb activation and phonomotor planning) and processing capacity limitations (e.g., working memory) create a bottleneck at the linguistic planning stage. Difficulties in verb retrieval and verb argument structure are likely a source of sentence production difficulties in agrammatism. The SPB is illustrated in Figure 1.

Figure 1

The Synergistic Processing Bottleneck Model of Agrammatism

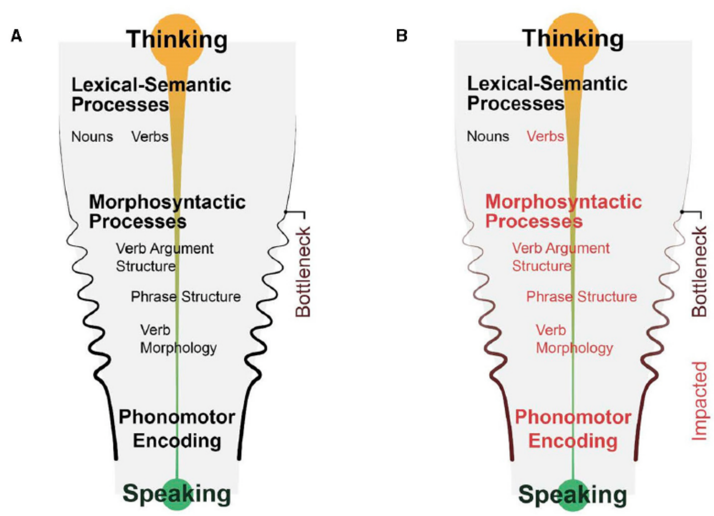


FIGURE 6
The *Synergistic Processing Bottleneck Model of Agrammatism*, showing sentence production in **(A)** neurotypical speakers, and **(B)** persons with agrammatic aphasia. Morphosyntactic computations (or constituent assembly) are a potential bottleneck due to the high processing load. Computations that are vulnerable in PSA-G due to LIFG lesion are noted in red font. These vulnerabilities exaggerate the processing bottleneck and result in slowly uttered, agrammatic speech output.

The SPB model predicts that agrammatic persons with aphasia will pause more frequently and for longer duration before verbs compared to persons with anomic aphasia. Further, persons with agrammatic aphasia will pause for shorter durations before nouns. Additionally, well-formed sentences will be associated with faster verb production. Conversely, if sentences are planned along with verb retrieval, then grammatical sentences will be associated with longer pauses.

Purpose of This Study

No known studies have investigated this three-way relationship between verb retrieval, agrammatism and pauses in the context of narrative speech. The specific goal of this study is to explore the relationship between verb retrieval, frequency, duration of pauses, and syntactic well-formedness in the narrative speech of persons with agrammatic aphasia. Persons with agrammatic aphasia will be compared to persons with anomic aphasia as well as neurotypical controls. The expectation is that a fine-grained analysis of pauses and verb retrieval at the utterance level may yield significant insights into the nature of agrammatism. This study will focus on lexical verbs in their entirety (that is, including any preceding auxiliaries, as in "…is pushing"). Copula verbs will not be analyzed because of syntactic and semantic differences with main verbs, and evidence that copulas might be used as part of stereotypical chunks by persons with agrammatic aphasia (Martínez-Ferreiro et al., 2020; Park et al., 2023). Further, this study will focus on within-utterance pauses and exclude analysis of between utterance pauses, as the latter may occur due to a variety of reasons, including turn-taking between conversational partners and topic emphasis. This approach is consistent with prior studies of pauses in aphasia (DeDe & Salis, 2020; Salis & Dede, 2022) and other neurodegenerative conditions (Lofgren & Hinzen, 2022; Pistono et al., 2019). Additionally, silent and filled pauses will be collapsed and analyzed. Although silent and filled can serve distinct functions in discourse, both types of pauses can reflect difficulties with word retrieval and utterance planning. Given that this study's focus on verb retrieval (a specific type of word retrieval) and utterance planning, both types of pauses could be combined and jointly considered as ways of stalling and buying time for word retrieval and utterance planning.

Research Questions

1. Within utterances, do persons with agrammatic aphasia produce more (and longer) pauses before verbs compared to persons with anomic aphasia? Conversely, do persons with agrammatic aphasia produce fewer (and shorter) pauses before nouns (within utterances, not initial subject nouns) compared to persons with anomic aphasia? This question has two independent variables: group (agrammatic, anomic) and word class (verb, noun). There are two dependent variables: number of pauses and duration of pauses. If difficulties in verb retrieval and verb argument structure are a source of sentence production difficulties in agrammatism, as suggested by the Synergistic Processing Bottleneck model (Faroqi-Shah, 2023), then agrammatic persons with aphasia will pause more frequently and for longer duration before verbs compared to persons with anomic aphasia. Further, persons with agrammatic aphasia will pause for shorter durations before nouns. Conversely, persons with anomic aphasia will pause for shorter durations before verbs than nouns.

2. In persons with aphasia, is the fluency of verb production within an utterance associated with a well-formed sentence? Fluency of a verb is defined as pre-verb pause length. The minimum pre-verb duration is zero in the case of co-articulation with the word occurring before a verb. This question has two independent variables, group (agrammatic, anomic) and utterance grammaticality (well-formed, ill-formed), and the dependent variable is pre-verb pause duration. If difficulties in verb retrieval and verb argument structure are a source of sentence production difficulties in agrammatism, as suggested by the Synergistic Processing Bottleneck model, then well-formed sentences will be associated with more fluent (faster) verb production.

Conversely, if sentences are planned simultaneous with verb retrieval, then grammatical sentences will be associated with longer pauses. Pre-verb pause duration will not differ between well-formed and ill-formed utterances in anomic aphasia.

Methods

Participants

Forty-five participants were selected from AphasiaBank (MacWhinney et al., 2011), 15 in each of the following groups: people with agrammatic aphasia, anomic aphasia, and neurotypical controls. Participants in the three groups were selected based on English as their primary language. The two clinical groups were selected based on having had a left hemisphere stroke. People in the agrammatic aphasia category were selected based on the sample's noun-verb ratio and open-closed class ratio values (see Appendix A, Faroqi-Shah, 2020). Larger noun-verb ratios and open-closed class ratio have been demonstrated to correlate with a diagnosis of agrammatic aphasia (Faroqi-Shah, 2020; Stark et al., 2023; Thompson et al., 1997; Thompson, 2003). For this study, the agrammatic criteria approximated the Faroqi-Shah (2020) agrammatic means for these measures, specifically the noun-verb ratio had to exceed 1.462 and the open-closed class ratio had to exceed .873 (see Appendix A for more). Using these "cut-off" scores yielded 24 agrammatic samples. Twenty of these agrammatic samples were reviewed before finding 15 with at least five verbs. People in the anomic category were classified based on the Western Aphasia Battery-Revised (Kertesz, 2006) as well as having lower noun-verb and open-closed class ratios than agrammatic participants.

As Table 1 shows, the two clinical groups (i.e., agrammatic aphasia and anomic aphasia) were similar in time post-stroke. The three groups were matched by age, years of education and gender. The groups with agrammatic and anomic aphasia were matched with respect to time post-onset of stroke but differed significantly with respect to the WAB-R Aphasia Quotient. Not surprisingly, the anomic group had higher aphasia quotients than the agrammatic group, consistent with their milder aphasia. The agrammatic group also had lower Verb Naming Test (Cho-Reyes & Thompson, 2012) scores, consistent with their verb deficit. Furthermore, each group's Cinderella narratives differed significantly by total number of utterances, word count, total duration, open/closed ratio, and noun/verb ratio. The higher noun-verb ratio of the agrammatic group compared to the anomic and control groups indicates their overall paucity of verbs compared to nouns in the language sample.

Table 1

Biographical characteristics and language measures of the participant groups and between-group comparisons

	Agrammatic	Anomic	Controls	Group comparisons
Age	59.6 (13.4)	57.4 (11.9)	58.4 (11.0)	*K-W(2) = 1.23, p = .54*
Education	17.2 (2.7)	15.6 (3.1)	15.4 (2.8)	*K-W(2) = 4.63, p = .10*
Gender	10 M, 5 W	7 M, 8 W	7 M, 8 W	*χ2(2) = 1.26, p = .53*
TPO	7.0 (6.0)	6.0 (5.3)	n/a	*U = 126, p = .60*
Test scores:				
WAB Aphasia Quotient (range: 0-100)	77.7 (12.8)	88.2 (5.0)	n/a	*U = 50, p = .03*
Verb Naming Test (range: 0-22)	16.5 (5.51)#	20.4 (1.68)	n/a	*U = 48.5, p = .012*
Boston Naming Test Short Form (range: 0-15)	9.86 (5.02)#	9.67 (3.94)	n/a	*U = 106, p = 1*
Language Measures from the Cinderella sample:				
Total Utterances	29.67 (12.57)	51.2 (22.63)	72.2 (59.37)	*K-W(2) = 11.52, p = .003*
Word Count	136.13 (53.7)	327.67 (128.21)	602.07 (385.74)	*K-W(2) = 28.59, p=<.001*
Total Duration	247.13 (79.8)	305.60 (224.72)	238.64 (136.51)#	*K-W(2) = 1.16, p = .56*
MLU	4.95 (1.62)	6.59 (1.89)	8.86 (1.87)	*K-W(2)=20.37, p=<.001*
% grammatical utterances	39.3 (32.5)	73 (27)	96 (9)	*K-W(2) = 45.28, p = <.001*
Open/Closed Ratio	1.56 (.52)	.93 (.17)	.96 (.09)	*K-W(2) = 26.60, p = <.001*
Noun/Verb Ratio	2.19 (1.31)	.81 (.19)	1.02 (.17)	*K-W(2) = 33.09, p = <.001*
% verbs	15.22 (4.05)	20.15 (1.38)	18.66 (1.37)	*K-W(2)=21.50, p=<.001*
% nouns	29.17 (5.55)	16.11 (3.40)	18.93 (2.48)	*K-W(2)=27.68, p=<.001*

Note. Values shown are mean (standard deviation), unless indicated otherwise. All comparisons are two-tailed. Age = in years; Education = in years; K-W(2) = Kruskal-Wallis test; TPO = time poststroke in years; Duration = in seconds; n/a = not available; U = Mann-Whitney test; WAB = Western Aphasia Battery; # = mean and SD computed for 14 values (one value missing).

Language Samples

All language samples came from the AphasiaBank database (English) (MacWhinney et al., 2011). AphasiaBank is a repository of interactions with persons with aphasia designed for researchers. As this study is interested in some of the same disfluency measures as Lynch (2022), AphasiaBank language samples that were divided into utterances and later transcribed by Lynch (2022) were used in this study. Each of these full transcripts from Lynch (2022) had been transcribed in CLAN per guidance put forth in *A Clinician's Complete Guide to CLAN and PRAAT* (Bernstein Ratner & Bundage, 2023). Sound files corresponding to each transcript were available in AphasiaBank (MacWhinney et al., 2011). The first narration of the Cinderella story in samples labeled as Broca's aphasia, Anomic aphasia, or Controls in AphasiaBank were screened for eligibility according to above participant criteria.

Analyses Procedures

Each language sample was analyzed one at a time in CLAN. In each sample, only the first narration of the Cinderella story (from gem @Cinderella to the next gem) was of interest. Once the Cinderella story was isolated from the rest of the AphasiaBank protocol, the next step was identifying the participant's first five non-initial (i.e. non-utterance initial) subject nouns (not pronouns) and the first five lexical (i.e. main) verbs. Each participant utterance, starting with the first utterance, was carefully reviewed to determine if it contained a non-initial subject noun and/or a lexical verb. Up to one noun and one verb per utterance were selected for inclusion. If an utterance contained neither a non-initial subject noun nor a lexical verb, then that utterance was skipped. If an utterance contained a non-initial subject noun and/or a lexical verb, then that utterance and the noun/verb were reviewed according to the following exclusion criteria: (1) CLAN utterance exclusion code [+ exc], (2) colloquial lexical verbs (e.g. hadta, gotta), (3) lexical verbs containing another part of speech between an auxiliary verb and the main verb (e.g. can also do), (4) gestures immediately prior to noun or verb production, and (5) same noun or verb as the utterance prior.

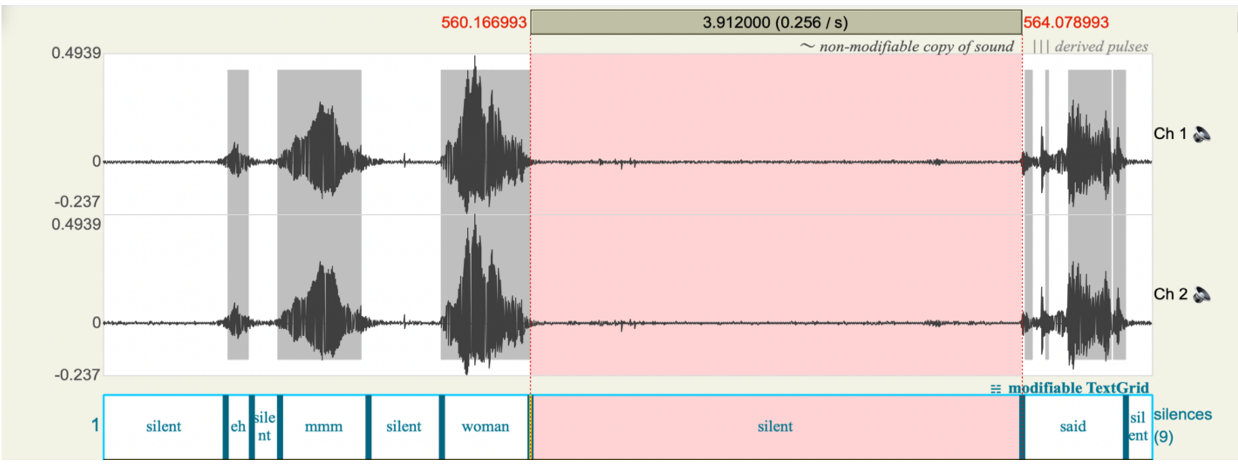
Utterances containing the first five qualifying nouns and verbs were exported from CLAN to Praat speech analysis software (Boersma & Weenink, 2023) using the 'Send to Sound Analyzer' feature. Each sound file was then divided into speech and silent segments using the "Annotate" function in Praat. Silent segments were set to > 200 ms – the duration used by DeDe & Salis (2020) in their study of pauses in aphasia. At this point, a new TextGrid was created. Both the sound file and the new TextGrid were selected to "View & Edit." What was displayed was the utterance's sound wave above the TextGrid with sounding and silent intervals.

Within each utterance, any pauses preceding the non-initial subject noun or lexical verb were of interest. At this point, the duration of the pause (filled and/or unfilled) was logged, and the part of speech following the pause (i.e. noun or verb) was noted. Furthermore, for each utterance, an annotation was made indicating whether an utterance was well-formed (a sentence free of any semantic, syntactic, morphological substitution or omission errors) or ill-formed (a phrase or a sentence with at least one semantic, syntactic, morphological substitution or omission error). Dysfluencies, slang, colloquialisms, and informal speech (e.g. wanna, gotta) were not considered errors, and use of these informal terms did not affect the well-formedness of an utterance. All data were recorded in an Excel spreadsheet.

For illustration, one utterance from an agrammatic aphasia participant is in Figure 2 (below). This utterance contained an eligible verb (said) and a silent pause before the verb lasting 3.91 seconds.

Figure 2

Sample Praat TextGrid with Sound Wave



Statistical Analyses

All statistical analyses were performed using SSPS version 27 (IBM Corporation). For the first research question, the number of pauses across groups and word types were compared using 2-way analysis of variance (ANOVA) with group and word class as the independent variables. Pause durations (dependent variable) were analyzed using generalized linear mixed models (GLM), with two fixed factors (independent variables): group (agrammatic, anomic) and word class (verb, noun). Participants were included as a random effect. For the second research question, a logistic regression was used to determine if utterance grammaticality (dependent variable) could be predicted by verb pause duration (independent variable). Separate logistic regressions were used for the anomic and agrammatic groups as these groups are expected to show a different relationship between verb retrieval and utterance grammaticality. For all analyses, $p < .05$ was considered significant.

Reliability

Pause durations were manually coded and logged in a spreadsheet by the author. Ten percent of these instances were then checked by another trained coder (Yasmeen Faroqi-Shah). Both coders used the same "zoom level" of the Praat window to display seven seconds of the waveform. There were no discrepancies that exceeded .01 seconds between the original and reliability coders.

Results

Pause measures across Groups and Word Class

Descriptive statistics of pause measures (i.e. number of pauses and pause duration) are shown in Table 2 and illustrated in Figures 3 and 4.

Table 2

The number and duration of pauses (in seconds) among the first five verbs and nouns for each group

	Nouns Mean (SD) [95% CI]			Verbs Mean (SD) [95% CI]		
	Number	Duration	% grammatical	Number	Duration	% grammatical
Control	.20 (.56) [-.11, .51]	.11 (.17) [.02, .21]	.93 (.12)	.27 (.46) [.01, .52]	.15 (.18) [.04, .24]	.99 (.05)
Anomic	.87 (.99) [.32, 1.41]	.65 (.64) [.29, 1.00]	.63 (.29)	.27 (.46) [.01, .52]	.48 (.51) [.20, .76]	.83 (.23)
Agrammatic	1.67 (1.45) [.87, 2.47]	1.59 (1.41) [.80, 2.37]	.41 (.34)	1.93 (1.58) [1.06, 2.81]	1.48 (1.26) [.78, 2.18]	.37 (.32)

For the number of pauses, the main effect of group was significant ($F (2, 84) = 19.45$, $p <.001$), with no significant effects of word class ($F (1, 84) = .17$, $p =.68$), or group x word class interaction (F(2, 84) = 1.47, p =.24). Pairwise comparisons with corrections for multiple comparisons (Bonferroni) showed that agrammatic group produced significantly more pauses than both anomic (Mean difference = 1.23, SE = .26, 95% CI = .59-1.88, p <.001) and control (Mean difference = 1.57, SE = .26, 95% CI = .92 – 2.21, p <.001) groups. The anomic and control groups did not differ significantly in the number of pauses (Mean difference = .33, SE = .26, 95% CI = -.98 -.31, p =.63).

Figure 3

The mean number of pauses among the first five verbs and nouns for each group. Error bars represent standard deviation.

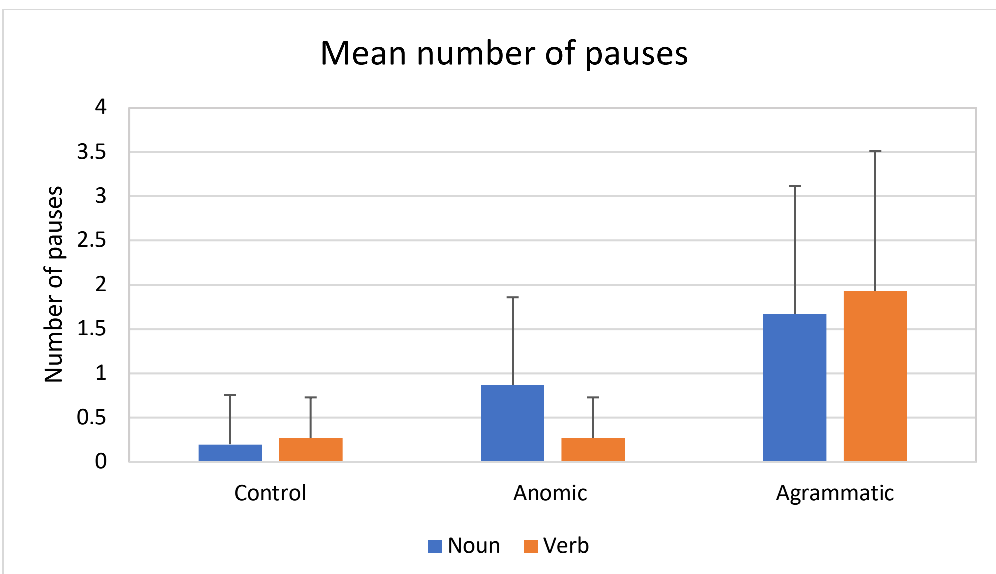


Figure 4

The mean duration of pauses among the first five verbs and nouns for each group. Error bars represent standard deviation.

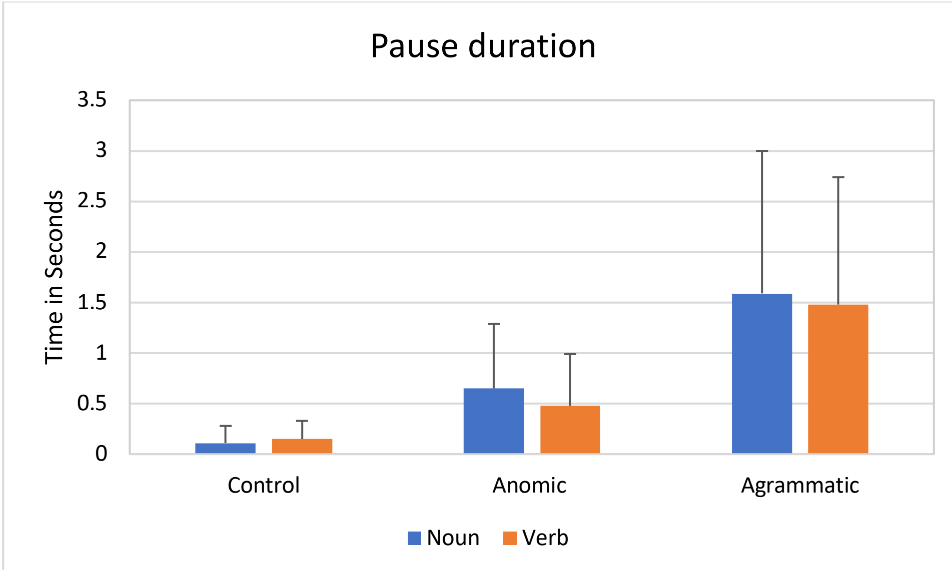


Table 3 contains the result of the pause duration statistical analyses. There was a main effect of group. Pairwise contrasts showed that relative to the agrammatic group, both the anomic and control groups had shorter pause durations, while the anomic and control groups did not differ from each other. There was no significant effect of word class or group by word class interaction. In summary, the agrammatic group produced longer pauses relative to the controls and the anomic group.

Table 3

Results of generalized linear effects mixed model, with group and word class as predictors for pause duration

Fixed Coefficients[a]

Model Term	Coefficient	Std. Error	t	Sig.	95% Confidence Interval Lower	95% Confidence Interval Upper
Intercept	1.480	1.0715	1.381	.168	-.626	3.586
Controls	-1.335	.2999	-4.453	.000	-1.925	-.746
Anomic	-.997	.2999	-3.324	.001	-1.586	-.407
Agrammatic	0[b]	.	.	.	.	.

Word Class = Noun	.108	.2226	.485	.628	-.330	.546
Word Class = Verb	0[b]	.	.	.	.	.
[Group=0]*[Word_class=1]	-.138	.3149	-.440	.660	-.757	.480
[Group=0]*[Word_class=2]	0[b]	.	.	.	.	.
[Group=1]*[Word_class=1]	.063	.3154	.200	.842	-.557	.683
[Group=1]*[Word_class=2]	0[b]	.	.	.	.	.
[Group=2]*[Word_class=1]	0[b]	.	.	.	.	.
[Group=2]*[Word_class=2]	0[b]	.	.	.	.	.

Note. Statistics run in SPSS.

a. Target: Pause_duration

b. This coefficient is set to zero because it is redundant.

Pairwise Contrasts

Group (0-controls, 1=anomic, 2=agrammatic) Pairwise Contrasts	Contrast Estimate	Std. Error	t	df	Adj. Sig.	95% Confidence Interval	
						Lower	Upper
control - anomic	-.439	.255	-1.720	443	.086	-.941	.063
control - agrammatic	-1.404	.255	-5.503	443	<.001	-1.906	-.903
anomic - control	.439	.255	1.720	443	.086	-.063	.941
anomic - agrammatic	-.965	.255	-3.779	443	<.001	-1.467	-.463
agrammatic - control	1.404	.255	5.503	443	<.001	.903	1.906
agrammatic - anomic	.965	.255	3.779	443	<.001	.463	1.467

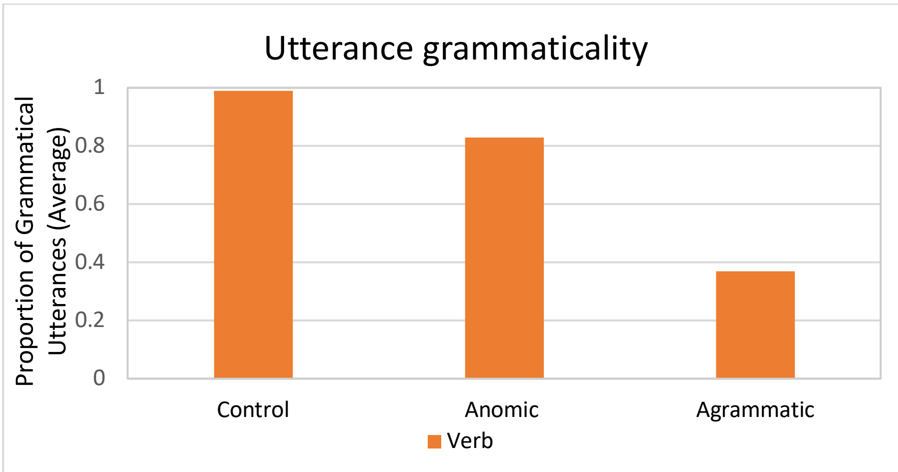
Note. The least significant difference adjusted significance level is .05.

The Relationship Between verb fluency and Utterance Grammaticality

As shown in Table 2, agrammatic individuals produced fewer grammatical utterances than anomic individuals. This difference was statistically significant (Mann-Whitney U = 37, p <.001). Utterance grammaticality for each aphasic group by word class is plotted in Figure 5. Information about the control group is also included for descriptive purposes but is excluded from this analysis.

Figure 5

The mean proportion of grammatical utterances among the first five verbs and nouns for each group. Error bars represent standard deviation.



The results of the logistic regression for pre-verb pause durations and utterance grammaticality in persons with aphasia are presented in Table 4. Utterance grammaticality was not predicted by pre-verb pause duration for anomic aphasia. For agrammatic aphasia, although the overall model approached significance, pre-verb pause duration was not a significant predictor of utterance grammaticality. To summarize, there was no strong evidence that the fluency of verb production within an utterance is associated with a well-formed utterance for either aphasia group.

Table 4

Logistic regression analysis of pre-verb pause durations and utterance grammaticality

	Overall model	Pause Duration			
		β (SE)	Wald χ^2	*p*	Exp(B) (odds ratio)
Anomic Aphasia	$\chi^2(1) = .31$, $p = .58$	-.15 (.26)	.343	.56	.861

Agrammatic Aphasia	$\chi^2(1) = 1.92$, $p = .166$	-.183 (.14)	1.624	.20	.833

Discussion

The broad goal of this study was to explore the relationship between verb retrieval, frequency of pauses, duration of pauses, and syntactic well-formedness in the narrative speech of persons with agrammatic aphasia. This study concentrated on two distinct questions related to the broad goal. The first question explored the relationship between the number of pauses, pause duration, and verb retrieval. The second research question examined the relationship between pre-verb pause duration and the syntactic well-formedness of that utterance. In interpreting the findings of the study, it is noteworthy that the agrammatic group showed significant verb retrieval difficulties overall, including picture naming and the proportion of verbs in the language sample (Table 1). The agrammatic group also showed utterance formulation difficulties, as evidenced by shorter utterance length and fewer grammatical utterances (Table 1).

The first finding of this study is that the agrammatic group produced significantly more pre-verb and pre-noun pauses than both anomic and control groups. This result is consistent with the hypothesis that the agrammatic group would produce a greater number of pre-verb and pre-noun pauses than the anomic and control groups. This is a new finding since no known study has examined the pauses immediately prior to lexical verb production and immediately prior to pre-non-initial subject noun production, both of which are highly specific locations within an utterance. More pauses at these precise moments within utterances may reflect ongoing difficulty with verb/noun production. Some similar studies (e.g. Angelopoulou et al., 2018; Zhang & Hinzen, 2022) also found that persons with aphasia generally pause more often than controls in connected speech, but each study has key methodological differences, limiting the extent that they support the present study. For example, Angelopoulou et al. (2018) analyzed narrative samples and found that individuals with aphasia took more pauses (mean = 54.06) versus controls (mean =19.75). However, this study aggregated all aphasia types into one group, ‘individuals with aphasia,’ which makes it impossible to distinguish pausing differences by aphasia subtype. This study also excluded filled pauses, and, more significantly, lumped pauses between utterances with pauses within utterances. Zhang & Hinzen (2022) measured overall ‘grammatical competence’ in persons with agrammatic aphasia versus controls, and, among other measures, compared mean pause length, as opposed to total numbers, of different pause measures (i.e. between g-units, between phrases and within phrases) by group. Pauses between g-units are essentially pauses between utterances – a measure that is irrelevant to this study. Furthermore, the within-utterance pause locations of interest to Zhang & Hinzen (i.e. between phrases and within phrases) differed from the pause locations of interest to this study (i.e. pre-lexical verb and pre-non-initial subject noun).

In addition, the agrammatic group produced longer pre-verb and pre-noun pauses than both the anomic and control groups. This result is also consistent with the hypothesis that the agrammatic group would produce longer pauses than the anomic and control groups. This is also a new finding since no known study has examined the duration of agrammatic pauses at specific locations within an utterance. A small body of literature has directly found that persons with aphasia take longer pauses than controls (e.g. Angelopoulou et al., 2018; Salis & DeDe, 2022); however, the clinical aphasia groups in both studies are not divided into agrammatic and anomic groups but instead are persons with any type of aphasia (as in Angelopoulou et al., 2018) or persons with anomic and latent (aphasia (as in Salis & DeDe, 2022).

Crucially, this study also found that the interaction between aphasia type, pause duration and word class (i.e. verb, noun) was not statistically significant. Although the agrammatic and anomic groups produced slightly more pauses for the word class that they have most trouble with (nouns for anomic and verbs for agrammatic), overall neither group was substantially slower with nouns versus verbs. It should be noted that an equal number of verbs and nouns were analyzed across groups; thus, when verbs and nouns were successfully retrieved, there was no quantitative difference between noun and verb pauses. This finding contradicts the hypothesis and body of research suggesting that persons with agrammatic aphasia would be significantly more impaired at verb retrieval as opposed to noun retrieval (e.g. Crepaldi et al., 2011; Lee & Thompson, 2004; Zingeser & Berndt, 1990). Nonetheless, these studies were all picture-naming studies and did not concentrate on agrammatic connected speech using the method employed by this study. In connected speech (as opposed to picture-naming), pauses may reflect not only semantic processes, but also syntactic processes related to incremental planning of utterances (Salis & DeDe, 2022). Therefore, upon adding the syntactic processing demands to verb/noun production tasks, persons with agrammatic aphasia produce fewer verbs and pause for similar durations pre-verb and pre-noun, suggesting that the planning demands could be similar. An alternate explanation is that since this study only examined non-utterance initial nouns and verbs, it is possible that the most relevant syntactic planning pauses occur between utterances. Consequently, the within-utterance pause durations do not capture planning costs.

Further, this study found no predictive relationship between pre-verb pause duration and utterance grammaticality. In other words, there was no strong evidence that the fluency or speed of verb production within an utterance is associated with a well-formed utterance for either aphasia group. This result contradicts the hypothesis that well-formed utterances will be associated with more fluent (faster) verb production. Thus, longer pre-verb pauses did not enhance utterance grammaticality, suggesting that pre-verb pauses are not facilitative. This is also a novel finding.

The findings related to first research questions (i.e. results concerning noun/verb pause frequency and duration by aphasia type) lend little support to the Synergistic Processing Bottleneck (SPB) model. The SPB identifies the source of sentence production challenges in agrammatism as verb-specific difficulties with certain morphosyntactic processes (i.e. verb argument structure, phrase structure and verb morphology) as well as with phonomotor encoding. Nevertheless, persons with agrammatic aphasia typically paused more often and for a similar duration prior to verbs in comparison to nouns. What is clear is that persons with agrammatic aphasia generally pause more and for longer than anomics and controls, no matter if the word post-pause is a noun or a verb. Perhaps the relatively high frequency and longer duration of pre-verb *and* pre-noun pauses in agrammatism suggest a broader noun and verb bottleneck impacting morphosyntactic and subsequently phonomotor encoding processes. As a result, it is possible that the SPB model should be expanded to account that nouns are also subject to morphosyntactic processing challenges as well as phonomotor encoding challenges. After all, although nouns may tend to have fewer syntactic constraints than verbs, correct use of nouns in connected speech still relies on both morphosyntactic processing and phonomotor encoding.

The findings related to the second research question (i.e. results related to duration of pauses and utterance grammaticality) differ from what is expected per the SPB model. This model implied that successful verb retrieval would lead to a higher likelihood of producing grammatically accurate utterances. In this study, success with verb retrieval was measured by pre-verb pause duration, which was not found to be associated with grammaticality (although there was a trend in this direction for agrammatic aphasia). Put another way, in any given utterance, the pre-verb pause duration, no matter whether it was relatively long or relatively short, was not associated with increases in grammaticality. This was unexpected as the initial expectation was that shorter pauses would result in improved grammaticality.

Nonetheless, it is possible that underlying semantic factors ultimately impacted pre-verb pause lengths and the overall grammaticality of an utterance. One possibility is that pre-verb pause durations are related to the number of arguments the subsequent verb takes. As mentioned in the Introduction, some verbs require more arguments or are more complex, and other verbs require fewer arguments or are simpler. Thus, production of more complex verbs, which need more arguments, might be associated with longer pre-verb pauses and less grammatical utterances, and production of shorter verbs, which need fewer arguments, might be associated with shorter pre-verb pauses and more grammatical utterances. Given that the present study did not account for verb complexity, it is unclear if this variable has an impact on pause duration and grammaticality overall. Another possibility is that pre-verb pause duration varies depending on whether the verb type is preferred by the speaker. For example, in connected speech, it has been suggested that individuals with aphasia favor semantically specific "heavy" verbs (e.g. run, bake, swim, drive) whereas others prefer semantically general "light" verbs (e.g. be, have, make, do) (Thorne & Faroqi-Shah, 2015). If someone with aphasia was retrieving a verb that differs from their preferred verb weight (i.e. either light or heavy), then it is possible that verb retrieval could be impacted, potentially resulting in a pause or delay prior to retrieval. Conversely, when someone retrieves a verb that aligns with their preferred verb weight, retrieval could occur more quickly. The present study did not account for the weight of the verb post-pause, so this factor could also impact pause durations and overall grammaticality.

It is also possible that linguistic demands associated with utterance length impacted pre-verb pause length and the overall grammaticality of an utterance. In their study of persons with latent (mild) aphasia, Salis and DeDe (2022) found that longer utterances were associated with more and longer pauses. The authors also posited that longer utterances may require increased working memory and more monitoring of what has been said (Salis & DeDe, 2022). Thus, assuming the same pattern holds true for persons with agrammatic aphasia, these underlying demands may contribute to utterance grammaticality.

Additionally, some evidence suggests that verb selection might not occur immediately prior to verb retrieval and instead occur at another point in the utterance. For example, based on a multiword picture-word inference task conducted in Japanese, Momma et al. (2015) demonstrated that verbs were selected prior to object noun articulation. This finding is potentially significant, for if same findings apply to English, then verb retrieval difficulties might not be accurately captured by the pauses occuring immediately prior to the verb. Instead, verb selection difficulties could be happening during other within-utterance pauses.

In sum, these variables not accounted for in the SPB (i.e. post-pause verb type, sentence length and verb selection location) might explain why the shorter pauses did not correspond with improved utterance grammaticality. Follow-up studies could further examine these variables to tease out which impact utterance grammaticality.

Limitations

This study has some limitations that should be addressed by future research. One limitation is the small sample size. With only 15 participants per category and five nouns and verbs per participant, the statistical power of our analyses is somewhat limited. We used only five verbs and nouns particularly because it was unrealistic to identify more than lexical five verbs in the agrammatic language samples. Another limitation of this study is that it did not account for dysarthria and apraxia of speech, although these two variables can also impact fluency (Matzig et al., 2009; Nozari & Faroqi-Shah, 2017). Future studies could address these limitations.

Conclusions

The purpose of this study was to explore the relationship between verb retrieval, frequency, duration of pauses, and syntactic well-formedness in the narrative speech of persons with agrammatic aphasia. We found that the number of pauses and pause duration differentiated persons with agrammatic aphasia from persons with anomic aphasia and neurotypical controls, yet verb retrieval and the syntactic well-formedness of an utterance did not significantly vary by aphasia type in utterances where verbs were successfully retrieved. The results were interpreted as not providing support to the Synergistic Processing Bottleneck model. The model may need to be revised to include both nouns and verbs.

Appendix A

Objective narrative speech measures for differentiating agrammatic from non-agrammatic aphasia

Measure	Neurotypical Mean (SD)	Non-Agrammatic PWA Mean (SD)	Agrammatic PWA Mean (SD)	Classification Accuracy (%)
Objective Measures (MacWhinney et al., 2011)				95.0
MLU in morphemes	9.7 (1.4) ***	6.8 (1.4) *	4.3 (2.1)	72.7
Verbs per utterance	1.6 (.2) ***	1.2 (.3) *	.7 (.5)	75.0
Density	.5 (.01) ***	.5 (.03) ***	.4 (.07)	75.0
Noun-verb ratio	1.1 (.1)	.8 (.3) ***	1.6 (.9)	72.7
Open-closed class ratio	.7 (.06)	.6 (.05) ***	1 (.5)	75.0
Index of productive syntax	95.7 (6) ***	89 (7) **	63.3 (18)	85.0

Note. Reference: Faroqi-Shah, Y. (2020). Diagnostic criteria for agrammatism: a critical analysis and empirical validation. *Academy of Aphasia*. Virtual Conference.

* $p < .05$. ** $p < .01$. *** $p < .001$.

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