How do individuals with aphasia cope with grammar?

Peters, Emma Lyne

College of Liberal Art and Sciences
The University of Iowa
Iowa City, Iowa

HOW DO INDIVIDUALS WITH APHASIA COPE WITH GRAMMAR?

By

Emma Lynne Peters

A thesis submitted in partial fulfillment of the requirements for graduation with Honors in the Department of Communication Sciences and Disorders

Doctor Jean K. Gordon

Thesis Mentor

Spring 2022

Abstract

Purpose: Aphasia is the loss of language abilities following damage to the regions of the brain responsible for language. Associated with aphasia are two patterns of disordered language production: agrammatism and paragrammatism. Agrammatism, associated with nonfluent aphasia, is characterized by the omission of function words (e.g., articles, prepositions) and inflections (e.g., -ing, -ed), while paragrammatism, which is associated with fluent aphasia, is characterized by the incorrect substitution of words and inflections. Although agrammatism is well documented, there has been little investigation of paragrammatism; its diagnosis is highly subjective. The current study aimed to explore the grammatical patterns of individuals with Broca's aphasia (and agrammatism) and Wernicke's aphasia (and paragrammatism) to better understand these disorders.

Methods: Using participants' narrative language samples taken from AphasiaBank, we examined utterance- and word-level errors, length of utterances, and the syntactic structures of utterances. Coding for utterance- and word-level errors had been previously completed by AphasiaBank contributors. Utterances were coded for their syntactic features (e.g., subject, verb phrase, prepositional phrase) to analyze syntactic structures.

Results: Individuals with Broca's aphasia produced twice as many grammatical errors per utterance, compared to individuals with Wernicke's aphasia. Individuals with Broca's aphasia most often produced utterances that were between one and three words in length; individuals with Wernicke's aphasia more frequently formed utterances that were between four and six words long. Our syntactic analysis demonstrated that individuals with Broca's aphasia more often used quotation embedding and other pseudo-grammatical structures in their utterances, whereas individuals with Wernicke's aphasia were better able to use syntactic elements like

objects and prepositional phrases. However, in their longer utterances, individuals with Wernicke's aphasia displayed their paragrammatic deficits by excessively and inappropriately embedding subordinate clauses in a way that caused syntax to be jumbled.

Conclusions: We found different patterns of language for individuals with Broca's aphasia (and agrammatism) and Wernicke's aphasia (and paragrammatism) in terms of their proportion of grammatical errors and syntactic abilities. These findings support the idea that agrammatism and paragrammatism are separate disorders with different characteristics.

Introduction

Aphasia is the loss of expressive or receptive language abilities caused by damage to the regions of the brain responsible for language. In most individuals, language is localized in the left cerebral hemisphere. Therefore, aphasia is typically the result of left hemisphere damage following a cerebrovascular accident (CVA), but may also arise from traumatic brain injury, brain tumors, or neurodegenerative diseases (Alexander & Hillis, 2008). Aphasia can affect all domains of language (spoken language, auditory comprehension, reading, and writing) but the symptoms, severity, and type of aphasia depend on the location and size of the lesion. Aphasia can be classified by the fluency of output. In nonfluent aphasia, language output is reduced, slow, and laborious. Grammar is often impaired, with only content words present in speech. Individuals with fluent aphasia usually have abundant language output and are able to produce connected speech. Sentences with more complex structures are often present in the output of individuals with fluent aphasia; however, these sentences will frequently lack meaning (American Speech-Language-Hearing Association, n.d.).

The types of aphasia with more fluent output include Wernicke's aphasia (WA), Conduction aphasia, Transcortical Sensory aphasia, and Anomic aphasia. Aphasia types with limited or nonfluent language output include Broca's aphasia (BA), Transcortical Motor aphasia, Global aphasia, and Mixed Transcortical aphasia. The present study will focus primarily on Broca's and Wernicke's aphasia because they show contrasting patterns of sentence productivity, the way they produce sentences, and the types of sentences they produce.

Wernicke's aphasia is typically associated with lesions to Wernicke's area, which is located on the left posterior superior temporal gyrus (pSTG). Lesions to Wernicke's area can also include damage to anatomical structures like the middle temporal gyrus (MTG), posterior supramarginal gyrus, or the inferior angular gyrus (Alexander & Hillis, 2008). The fluent output

associated with Wernicke's aphasia almost always contains preserved aspects of grammatical and syntactic structure. While there is fluent output in WA, the output often contains many errors. Paraphasias are word errors that can result from an incorrect substitution of a target word or the changing of sounds in a target word. Both semantic paraphasias, which involve the substitution of words related to each other by meaning, and phonemic paraphasias, which involve words that sound alike, may be present in the speech of individuals with Wernicke's aphasia. Neologisms, made-up words, and jargon, incomprehensible strings of made-up words or real words, are also present in the speech of people with Wernicke's aphasia (Le & Lui, 2021). Because individuals with Wernicke's aphasia commonly have deficits in language comprehension, these errors are often not recognized by people with WA. In addition to not recognizing their errors, the comprehension of others' speech is impaired, often severely.

In contrast to Wernicke's aphasia, Broca's aphasia generally results from lesions to Broca's area, which is located on the left inferior frontal gyrus. People with Broca's aphasia typically have relatively preserved comprehension skills accompanied by non-fluent spoken language. The language output of people with Broca's aphasia contains mostly content words, with some omissions of grammatical elements, causing speech to be telegraphic. Semantic and phonemic paraphasias are also present in the speech of people with Broca's aphasia (Alexander & Hillis, 2008).

As stated by Matchin et al. (2020), Kleist (1914) was the first to describe two separate grammatical patterns of output in people with aphasia: agrammatism and paragrammatism. Agrammatic speech is characterized by omissions of grammatical morphemes, whereas paragrammatic speech is characterized by the substitution of grammatical morphemes (Kleist, 1916, as cited by Butterworth, 1994). More specifically, agrammatism is associated with a

simplified syntactic structure and the omission of function words (e.g. prepositions, articles) and inflections (Butterworth, 1994). Saffran et al. (1980) provide an example of a subject's agrammatic speech, "Like the door...crash...like, pants...shirt...shoes...the boy...the dress… I dunno" (p. 223). Paragrammatism, conversely, involves the substitution or incorrect usage of inflections and words along with confused, sometimes complex, syntax (Butterworth, 1994). Butterworth and Howard (1987) provide an example of paragrammatic speech, "Want a good towels" (p. 18). More research has been done investigating agrammatism, while paragrammatism has not been as thoroughly studied. It is well documented that agrammatism is linked with nonfluent aphasia (mostly BA) and paragrammatism is linked with fluent aphasia (mostly WA or conduction aphasia) (Matchin et al., 2020).

There has always been controversy surrounding the idea of agrammatism and paragrammatism as distinct grammatical disorders. Although Kleist (1914) first proposed that agrammatism and paragrammatism were separate grammatical disorders, in 1916, he reversed this stance and instead claimed that they were two sides of the same coin (De Bleser, 1987). However, in 1934, Kleist returned to his original stance and reasserted that agrammatism and paragrammatism were caused by damage to different regions of the brain, the frontal and temporal lobe, respectively. Present researchers are still in disagreement as to whether agrammatism and paragrammatism should be thought of as different disorders. Some researchers, such as Butterworth and Howard (1987) and Kolk and Heeschen (1992), have theorized that paragrammatism is not a unique disorder. By contrast, recent work by Matchin and Hickok (2020) and Matchin et al. (2020) has garnered support for Kleist's (1914) and (1934) theory of agrammatism and paragrammatism, claiming that they are separate disorders that arise from damage to different regions of the brain.

In their 1987 study, Butterworth and Howard reviewed and investigated four broad theories about the nature of paragrammatism. The first theory suggested that paragrammatism is the result of a syntactic disturbance, in which the rules for generating phrases have been corrupted or the filters on phrase generation have stopped functioning. The second theory claimed that paragrammatic output arises purely from a lexical selection impairment. The third theory stated that paragrammatism is due to a lack of monitoring of output in speech. Non-brain damaged speakers have a functional monitoring system that catches and corrects errors in their speech before they are produced. Within the framework of this third theory, the monitoring system of individuals with paragrammatism is permanently damaged; therefore, paragrammatic errors are not edited out by the system and are present in speech. Lastly, the fourth theory claimed that paragrammatic errors are not the result of a permanent impairment to the language production system, but rather are the result of brief breakdowns of a working system. Therefore, paragrammatic errors can be thought of as no different from the slips-of-the-tongue of non-brain damaged speakers, and these errors are just produced more frequently in individuals with paragrammatism.

To test these theories, Butterworth and Howard analyzed the conversational speech of five patients with paragrammatism and four non-brain damaged speakers. The ungrammatical sentences were selected from their speech, and the errors that rendered the sentences ungrammatical were analyzed. From their analyses, it was found that paragrammatic errors occurred in non-brain damaged speakers as well as speakers with agrammatism. Butterworth and Howard (1987) believed that their evidence supported their fourth theory, that paragrammatic errors are the same types of errors found in the productions of non-brain damaged speakers. They suggested that paragrammatic errors arise from brief disruptions of an intact language production

system, rather than from lasting damage to specific processing components. Because of this, they concluded that paragrammatism should not be considered a separate or unique pattern of aphasic impairment that is specific to people with fluent aphasia.

Kolk and Heeschen (1992) hypothesized that differences in the output of individuals with agrammatism and paragrammatism are due to a strategic adaptation of speakers with agrammatism. They maintained that individuals with Broca's aphasia and agrammatism will consciously adopt an elliptical style of speaking to avoid producing paragrammatic errors, depending on the goals of their speech. For instance, if a speaker needs to convey a more complex message, they may choose to drop their telegraphic style of speaking to include more information in their speech. In support of this, their analyses showed that the output of individuals with agrammatism could become less agrammatic in social situations that required more complex sentence forms.

This elliptical style of speaking involves producing fragments of speech that lack a finite verb, or any verb at all (e.g. "two months unconscious") (Kolk & Heeschen, 1992). Kolk and Heeschen claimed that individuals with paragrammatism do not try to prevent grammatical errors in this way. Two theories are offered for why this might be. First, they proposed that individuals with Broca's aphasia and agrammatism spend more time, and are better at, monitoring the errors in their speech than are individuals with Wernicke's aphasia and paragrammatism. They cite an idea proposed by Kolk and van Grunsven (1985) that individuals with Broca's aphasia engage in a process called corrective adaptation. In this process, the mental representation of a sentence that individuals with Broca's aphasia form falls apart before the speaker can produce their utterance. Because of this, individuals have to remake their original representation of the sentence they want to produce. This regeneration of the sentence representation allows

individuals to self-correct and repair the errors in the utterance before it is spoken. The second theory posed to explain the elliptical strategy difference between individuals with agrammatism and paragrammatism claimed that individuals with Wernicke's aphasia have some feature that helps them maintain speed and fluency during speech. Because this factor works to maintain the speed of speech, individuals with Wernicke's aphasia do not employ processes to monitor or repair speech because they take too much time. Because of their findings, they concluded that individuals with Broca's aphasia (and agrammatism) and Wernicke's aphasia (and paragrammatism) have the same processing deficit with regard to grammatical productions, but adapt to it differently.

Unlike Butterworth and Howard (1987) and Kolk and Heeschen (1992), Matchin and Hickok (2020) theorized that agrammatism and paragrammatism are different disorders that do not share an underlying deficit and proposed a model for the cortical organization of syntax in line with this theory. Within this model, language production begins with a conceptual representation formed in the anterior temporal lobe/angular gyrus. This conceptual representation is then converted into a hierarchical lexical-syntactic representation in the pMTG. Next, the hierarchical representation is used to construct a morphosyntactic linear sequence in the inferior frontal region of the brain. Using this framework, the authors assert that paragrammatism is the consequence of an impairment of the hierarchical representations with unaffected morphosyntactic sequencing rules. Because of this, hierarchical relationships are not well constrained, leading to paragrammatic errors. To illustrate this, Matchin and Hickok (2020) provide an example of the paragrammatic error, "the birds was a color," taken from Yagata et al. (2017). This error is an agreement error that involves a mismatch in the number feature between the subject (bird) and the verb (was). In this example, the authors propose that the hierarchical

representation that exists between the subject and the verb is not present, so the two words are susceptible to disagreement of number features. However, it is unclear what the nature of this error is (incorrect plural -s or incorrect inflection of the verb) and Matchin and Hickok do not provide a broader explanation as to how their model can account for a wider range of paragrammatic errors.

While hierarchical lexical-syntactic representations may be impaired for individuals with paragrammatism, output remains relatively fluent because morphological sequencing is preserved. On the other hand, agrammatism is hypothesized to arise from damage to the sequencing mechanism, accounting for the reduced output and omission of grammatical elements (e.g. articles, prepositions, inflections) common in agrammatism. This theoretical model of language production establishes agrammatism and paragrammatism as separate grammatical disorders that arise from damage to different brain structures.

Matchin et al. (2020) provide evidence for this theory of the cortical organization of syntax, suggesting that agrammatism and paragrammatism are distinct disorders. In this study, lesion mapping was used to investigate the association between specific brain regions and agrammatism and paragrammatism. The data collected supported the idea that there is a clear double dissociation between agrammatism and paragrammatism and the lesions associated with each. More specifically, it was found that agrammatism, but not paragrammatism, is significantly associated with damage to Broca's area, and that paragrammatism, but not agrammatism, is significantly associated with damage to the left pSTG and MTG. These findings indirectly indicate that paragrammatism is a disorder distinct from agrammatism, involving different regions of the brain.

The present study aimed to explore the different patterns of language production in individuals with Broca's and Wernicke's aphasia by examining utterance-level errors, word-level errors, length of utterance, and the syntactic structures of common utterance to further study the characteristic language impairments resulting from agrammatism and paragrammatism.

Methods

Participants

In this study, twenty individuals were selected from the AphasiaBank database because they had been diagnosed as having Wernicke's aphasia by both their WAB type and clinical type. A one-to-one matching procedure was completed to match the twenty individuals with WA to twenty individuals with BA (from a pool of 88 total individuals with BA in the AphasiaBank database). Potential participants were matched within three points of their Western Aphasia Battery Aphasia Quotient (WAB-AQ) scores (Kertesz, 1982). WAB-AQ scores are a measure of aphasia severity and were used for matching to control for aphasia severity for individuals with different aphasia types. Additionally, participants' age, education level, and gender were also considered while matching, so that the groups were as similar as possible demographically. For instance, if there were two PwA who had similar WAB-AQ scores, we selected the individual who had the same gender, and was a similar age, with a similar educational level as the participant they were being matched to. Participants were excluded from consideration for matching if one of the narrative tasks used to assess their language skills, described below, was not administered to them or if the participant had refused to participate in any of the tasks. The demographics of the participants with WA and BA are displayed in Table 1.

TABLE 1 Participant Demographics of Individuals with Wernicke's Aphasia Matched with Individuals with Broca's Aphasia

Wernicke's Aphasia	Age at Testing(years)	Sex	Educ (years)	WAB-AQ	Broca's Aphasia	Age at Testing (years)	Sex	Educ (years)	WAB-AQ
Adler06a	70.6	M	12	30.2	Scale03a	52.8	M	12	28.1
Tucson03a	46.8	F	19	34.5	Kansas16a	63.5	M	12	32.4
Williamson23	60.8	M	16	36.8	Kurland22a	80.0	M	8	35.7
Kurland16a	70.0	M	12	37.1	Tap06a-fixed	72.8	M	20	38.2
Tucson15a	74.1	M	16	43.1	Tap13a	49.3	F	16	44.4
Kurland18a	74.3	M	16	44.0	Elman06a	76.9	F	16	45.5
Adler23a	81.3	M	NA	46.8	Whiteside03a	76.5	F	12	47.2
ACWT11a	61.7	M	16	49.9	Whiteside04a	65.4	M	12	50.0
Whiteside10a	68.3	M	16	52.0	UNH09a	65.9	M	13	50.8
Garrett01a-fixed	76.7	F	17	52.4	Scale01a	78.3	M	18	52.5
Kansas23a	75.6	F	12	54.7	Whiteside16a	46.8	F	12	53.4
Kurland01a	57.8	M	16	55.7	Adler13a	52.4	M	18	55.8
Williamson06	88.2	F	20	60.1	Tap17a	65.5	F	12	59.5
Scale38a	70.8	M	16	63.8	ACWT01a	69.9	F	18	63.9
BU10a	75.8	M	18	65.1	Scale26a	58.8	M	16	64.8
Elman14a	76.3	F	17	65.7	Elman03a	55.2	M	20	66.2
Scale11a	90.7	F	12	65.9	Scale36a	55.2	M	15	66.3

Williamson16a	63.5	F	16	66.4	Kurland19a	70.5	F	12	67.2
Kansas14a	77.4	F	17	67.4	Williamson11a	64.8	F	16	68.0
Elman12a	57.4	M	20	74.4	Kurland02b	72.8	M	23	74.7
Mean	70.9	-	16.0	53.3	**Mean**	64.7	-	15.1	53.2
SD	10.6	-	2.5	12.8	**SD**	10.2	-	3.7	13.2
# of Males, Females	-	12, 8	-	-	**# of Males, Females**	-	12, 8	-	-

Groups were not significantly different in years of education ($p = .35$) or WAB-AQ ($p = .99$). The sex distribution was the same for both groups, with each group consisting of twelve men and eight women. Differences in age between the individuals with Wernicke's aphasia and Broca's aphasia approached significance ($p = .07$), with the Wernicke's aphasia group having a higher mean age. A literature review examining the relationship between age and aphasia, by Ellis and Urban (2016), identified twelve studies that all found the trend of individuals with Broca's aphasia being significantly younger than individuals with Wernicke's aphasia. Therefore, it is not unusual that in this study, the group of individuals with Wernicke's aphasia were older than the group of individuals with Broca's aphasia.

Speech samples

For this study, three types of discourse elicitation tasks were used to obtain speech samples. The tasks utilized were picture description tasks, a story retell task, and a procedural narrative task. Each of these tasks elicits slightly different language and narratives from individuals. For example, an individual may adopt a different narrative or language style when describing how to make a peanut butter jelly sandwich compared to when telling a fairytale like Cinderella. Moreover, Fergadiotis and Wright (2011) found that, for persons with aphasia, the lexical diversity of a language sample varies with the type of discourse task. To be sure we fully captured individuals' complex language abilities, we chose to examine the language produced during multiple discourse tasks.

Each participant completed three picture description tasks: Broken Window, Refused Umbrella, and Cat Rescue. During the picture description tasks, an individual was presented with an image or series of images and was told to use the pictures to tell a story with a beginning,

middle, and end. The subject was allowed to look at the pictures as they told their story. The descriptions of the different picture description tasks used in this study are as follows:

Broken Window: The participant is presented with a series of four line drawings that depict a boy kicking a soccer ball through a man's window.

Refused Umbrella: The participant is presented with a series of six line drawings that depict a boy refusing an umbrella from his mother, getting rained on, and then returning to his mother to get the umbrella.

Cat Rescue: The participant is presented with a line drawing that depicts a cat and a man stuck in a tree, with a girl and dog on the ground below. Two firemen with a ladder appear to be coming to the aid of the man and the cat.

The story retell task used was the **Cinderella Story**. In this task, participants are presented with a wordless picture book that tells the story of Cinderella. After they finish looking through the picture book, it is taken away, and participants are asked to tell the story of Cinderella by referring to the pictures they saw and any other information they know about the Cinderella story. In this study, one participant was allowed to use the Cinderella storybook while generating their narrative.

The procedural discourse task was the **Peanut Butter and Jelly Sandwich task**. During it, participants are asked to describe how they would make a peanut butter and jelly sandwich. If they are unable to produce a verbal response to this prompt, they are given a picture of a jar of peanut butter, a jar of jelly, and a slice of bread to aid their response (MacWhinney et al., 2011).

The participants' transcripts were taken from the AphasiaBank database and therefore already contained codes for different types of utterance and word-level errors. The

coding of both utterance-level and word-level errors had been previously completed by AphasiaBank contributors.

Utterance-Level Codes

Utterances were coded with [+gram] when an utterance or part of an utterance was grammatically incorrect. The [+jar] code marked utterances that contained jargon. When an utterance contained empty speech, the code [+es] was used. Lastly, circumlocutions were coded with the [+cir] code. Because the present study examines two grammatical disorders, utterances marked with the [+gram] were of particular interest, as they denoted utterances containing grammatical errors.

Word-Level Codes

If the participant made a semantic word error, the code [*s] followed the word with the error. The code [*ur] was used to indicate errors where an individual produced an unrelated word. If an error was phonological, the error was categorized as either a phonological error that resulted in the production of a real word (coded as [*p:w]) or a non-word (coded as [*p:n]). Neologistic errors were coded as [*n:k] when the target word was known and as [*n:uk] when a neologism was produced with an unknown target. Morphological errors were indicated by the code [*m]. Lastly, instances of perseveration were coded using a [*per] code (MacWhinney, 2000).

Additional Coding

To analyze the participants' language samples, we downloaded individuals' transcripts from the AphasiaBank database and converted these transcripts into Microsoft Excel Files, with each utterance in the transcript on a separate line. Only utterances that were relevant to the task

were included in these files, with comments and questions about the task (e.g., “I can’t say it” or “What do you call her?”) or other irrelevant task deviations (e.g., “Oh words, so many words”) being excluded.

Next, we extracted the most relevant information from the utterances to form “core utterances”. First, these core utterances excluded any non-meaningful word or phrase repetitions. Typically, meaningful repetitions included the repetition of a phrases or content word (e.g., verb, adjective, noun) in a purposeful way that conveyed new meaning or meaningful emphasis to the narrative (e.g., saying, “raining, raining, raining,” to express how hard it was raining). Conversely, a non-meaningful repetition was one where the participant reproduced a word or phrase without a discernable communicative purpose (e.g., “with the, with the, with the, the mama and the two daughters”). Additionally, core utterances did not include words errors that were immediately corrected or repaired (e.g., “looking <out the> // outside”), existing AphasiaBank glosses, initial conjunctions that did not contain meaningful information (e.g., and, so, but), or any other language within an utterance that was not relevant to the specific narrative task.

Coding of these core utterances was completed by a three-person team consisting of one graduate and two undergraduate students. First, each member of the team coded the core utterances from a participant’s transcript individually. Then the team met together to review the transcript files and resolve any disagreements in their codes.

Quantitative Analyses

The total numbers of utterances and words from every individual’s language sample were counted. To get a word count, we used only the words present in each core utterance. The total

numbers of errors, at both utterance and word levels, were also counted for each error type. Means and standard deviations for the number of utterances, total words, and errors were calculated for the Wernicke's and Broca's groups and t-tests were conducted to examine the significance of the group differences.

Because individuals with Wernicke's aphasia were expected to have longer language samples, we also divided the utterance-level and word-level error data by the total number of utterances or words, respectively, in an individual's sample. Doing this allowed us to examine the proportions of errors per utterance or per word, as well as words per utterance (WPU). We examined the WPU data from each individual's language sample and then compared the distributions of WPU for individuals with Broca's and Wernicke's aphasia.

Qualitative Analyses

To examine the syntactic patterns of individuals with BA and WA, we conducted a qualitative analysis of the most common syntactic structures and features used in the utterances for each group. We examined a subset of twenty of the one-word utterances from individuals with BA and subsets of twenty three- and five-word utterances from individuals with BA and WA. These utterance lengths were chosen because individuals with BA most often produced utterances that were between one and three words long, while individuals with WA most commonly produced utterances that were between four and six words long. The one-word utterances from individuals with BA were coded for the part of speech that was used, either a noun (N), pronoun (ProN), verb, adjective (Adj), or other (onomatopoeias, exclamations, and neologisms). The three- and five-word utterances were coded for their syntactic structures. The syntactic structure of each utterance was coded by the features described in Table 2.

TABLE 2 Syntactic Features and Categories for Analyses (with examples)

Syntactic Structure	**Elements Included in Each Structure**
Main Clause	
Subject Noun Phrase (Sub)	Noun (“boy”), Noun Phrase (“the girl”), Pronoun (“this”)
Verb Phrase (VP)	Verb (“kicking”), Verb Phrase: Auxiliary + Verb (“is holding”), Verb + Adverb (“catch it there”)
Object Noun Phrase (Ob)	Noun, Noun Phrase, Pronoun
Adjective Phrase (Adj)	Adjective (“bad”); Adjective Phrase (“very bad”)
Prepositional Phrase (PP)	Prepositional Phrase (“in the air”)
Subordinate Clause	
Quote (Quot)	Embedded Quote (“man, ‘oh hey’”)
Other Structures	
Other	Exclamations (“Oh my God”), Questions (“what is that”), Onomatopoeia (“ruff ruff ruff”), Counting (“two, three, four”), Neologisms (/bɪzɪz/), Stand-alone Conjunctions (“and”), Stand-alone Adverbs (“right here”)

To gain more insight into individuals’ paragrammatic deficits, we more closely examined the syntax of some of the longer utterances from individuals with WA. Specifically, we were interested in utterances that contained paragrammatic errors and were longer than fifteen words.

Results

Matching

Although the two group were matched on WAB-AQ, group differences were significant for WAB Fluency scores ($p < .01$), as expected. The individuals with Wernicke's aphasia's fluency scores ranged from 6 to 8, with a mean score of 7.3 and a standard deviation of 0.8. Individuals with Broca's aphasia's fluency scores ranged from 1 to 5, with a mean score of 3.3 and a standard deviation of 1.1.

Utterance-and Word-Level Errors

Individuals with Wernicke's aphasia produced significantly more utterances ($p<.01$) and total words ($p<.01$) in their language samples than individuals with Broca's aphasia. From the raw utterance-level error data, we found that individuals with Wernicke's aphasia produced significantly more jargon ($p=.03$), circumlocutions ($p=.02$), and empty speech ($p<.01$) than individuals with Broca's aphasia. From the raw word-level error data, we found that individuals with Wernicke's aphasia made significantly more semantic ($p<.01$) and unrelated ($p<.01$) errors than individuals with Broca's aphasia. Additionally, individuals with WA produced significantly more word-level errors than individuals with BA ($p=.02$). The corresponding mean and standard deviation values can be found in Table 3.

TABLE 3 Quantitative Data Mean Values

	Broca's Aphasia		Wernicke's Aphasia		p (mean number, mean proportion)
	Mean number (SD)	**Mean proportion (SD)**	**Mean number (SD)**	**Mean proportion (SD)**	
Utterances	49.1 (28.6)	-	79.2 (35.4)	-	.01*
Words	144.5 (98.0)	2.89 (1.17)	504.8 (261.9)	6.38 (1.42)	<.01*, <.01*
Utterance-level errors					
[+gram]	29.1 (18.1)	0.595 (.219)	22.8 (12.3)	.297 (.111)	.20, <.01*
[+jar]	2.6 (3.3)	0.076 (.124)	12.6 (18.4)	.165 (.229)	.03*, .14
[+cir]	0.3 (0.7)	0.006 (.013)	1.6 (2.3)	.018 (.028)	.02*, .10
[+es]	4.8 (5.8)	0.097 (.109)	18.25 (14.6)	.231 (.154)	<.01*, <.01*
Word-level errors					
[*s]	3.9 (3.5)*	.028 (.021)	12.3 (11.1)	.026 (.020)	<.01*, .69
[*ur]	1.1 (1.5)	.013 (.020)	9.7 (11.8)	.021 (.018)	<.01*, .20
[*p:w]	2.7 (5.6)	.019 (.035)	3.8 (3.2)	.008 (.006)	.47, .16
[*p:n]	5.5 (10.3)	.040 (.061)	3.1 (3.3)	.006 (.004)	.33, .02*
[*n:k]	1.7 (3.9)	.014 (.031)	2.3 (2.7)	.005 (.006)	.61, .20
[*n:uk]	2.3 (3.7)	.027 (.053)	7.8 (12.0)	.018 (.029)	.07, .51
[*m]	1.1 (1.7)	.005 (.007)	1.2 (1.5)	.002 (.002)	.85, .08
[*per]	1.3 (1.9)	.016 (.028)	2.7 (8.0)	.004 (.011)	.45, .09
Total Word-Level	17.1 (21.8)	.146 (.155)	38.3 (32.8)	.083 (.054)	.02*, .10

*Asterisks after p values are used to indicate significant differences between BA and WA groups ($p<.05$). [+gram] = grammatical errors, [+jar] = instances of jargon, [+cir] = instances of circumlocution, [+es] = empty speech errors, [*s] = semantic errors, [*ur] = unrelated errors, [*p:w] = phonological errors resulting in a real word, [*p:n] = phonological errors resulting in a non-word, [*n:k] = neologistic errors when the target word was known, [*n:uk] = neologistic errors with unknown targets, [*m] = morphological errors, [*per] = perseveration errors.

Figure 1 shows the mean numbers of utterance-level errors of each type as a proportion of total utterances. The corresponding mean and standard deviation values can be found in Table 3. Two types of errors were significantly different between the BA and WA groups. Individuals with Broca's aphasia produced significantly more grammatical errors per utterance (.595) than individuals with Wernicke's aphasia (.297) ($p<.01$). Additionally, individuals with Wernicke's aphasia produced significantly more empty utterances (.231) than individuals with Broca's aphasia (.097) ($p<.01$).

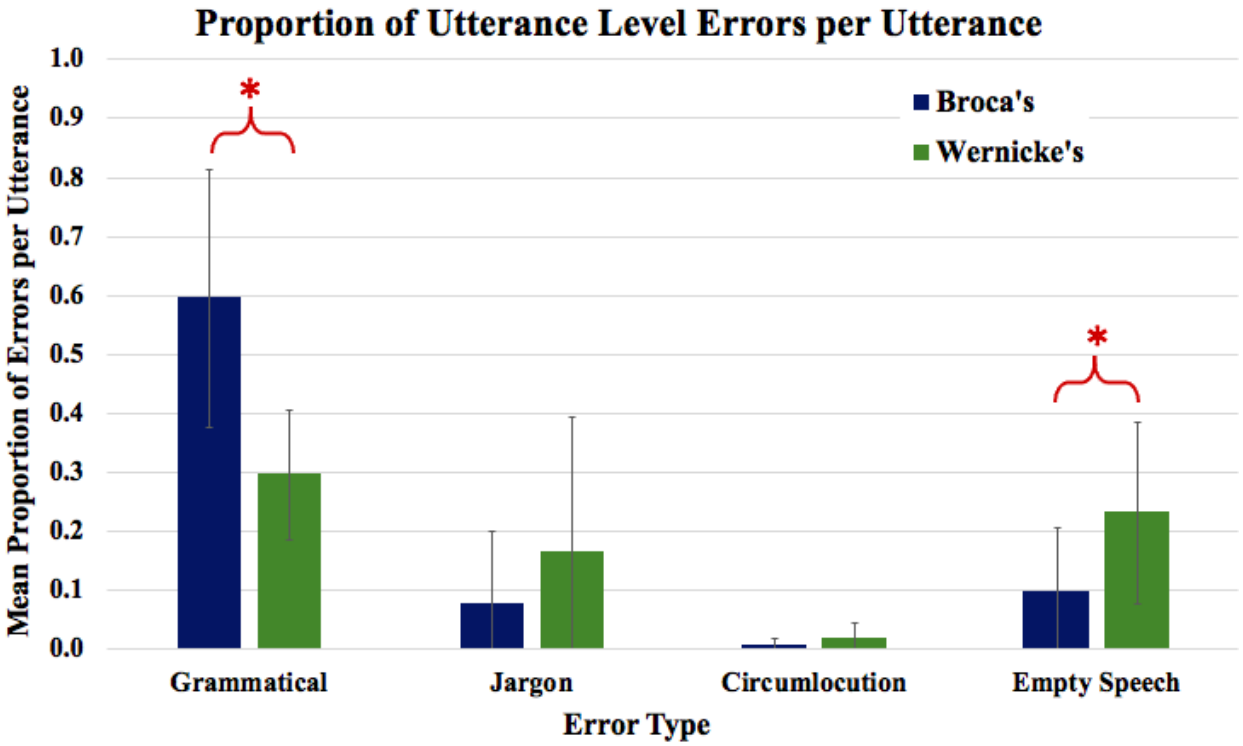


***Figure 1**: Graph of utterance-level errors as a proportion of total utterances for individuals with Broca's and Wernicke's aphasia. Significant group differences ($p<.05$) are indicated by the asterisk and bracket above the bars.*

Figure 2 displays the mean number of errors per word for each of the word-level error types. Only the production of phonological non-word errors was significantly different for the two groups (p=.02); individuals with Broca's aphasia produced more phonological non-word errors per word (.040) than individuals with Wernicke's aphasia (.006). The corresponding mean and standard deviation values can be found in Table 3.

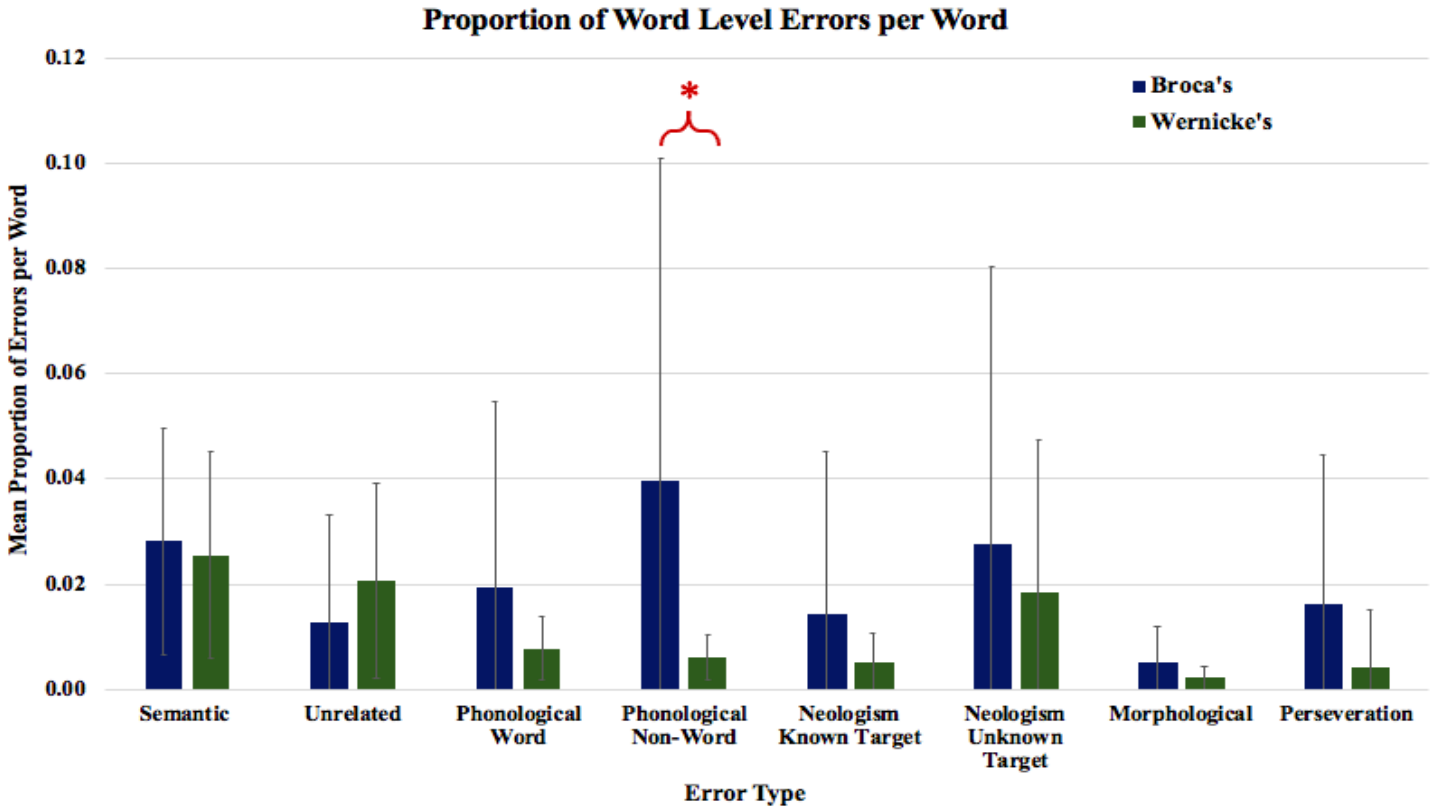


***Figure 2**: Graph of word-level errors as a proportion of total word for individuals with Broca's and Wernicke's aphasia. Significant group differences (p<.05) are indicated by the asterisk and bracket above the bars.*

Words Per Utterance

Individuals with Wernicke's aphasia used significantly more words in their utterances (6.38) than individuals with Broca's aphasia (2.89) ($p<.01$). Figure 3 shows a histogram of WPU for both groups made from all utterances in every individual's language sample. From this histogram, one can see that the individuals with Broca's have a bimodal distribution, with the first mode at one word per utterance and a second mode at three words per utterance. The distribution for the individuals with Wernicke's aphasia was positively skewed, with a mode at five words per utterance.

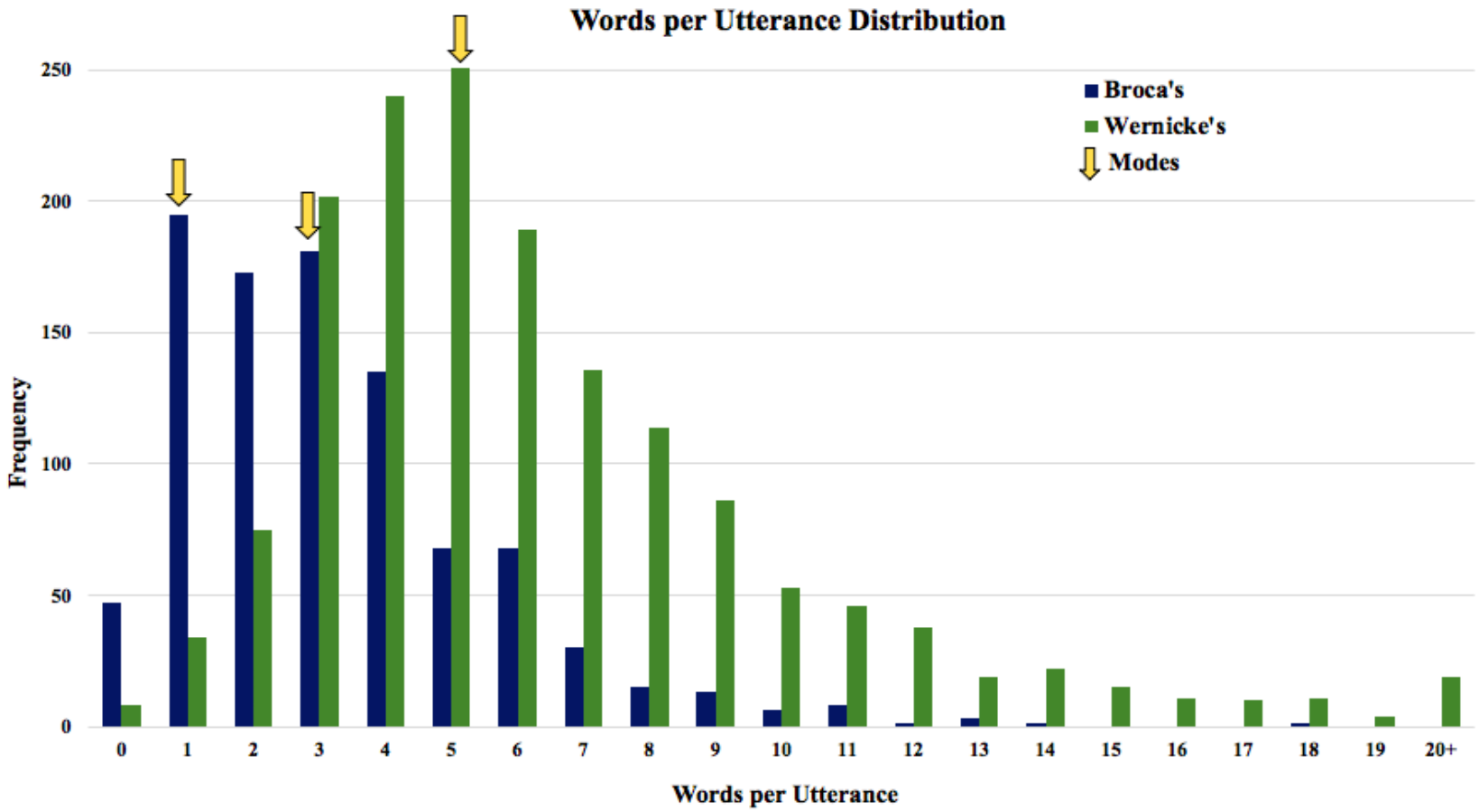


Figure 3*: Histogram displaying the distribution of the words per utterance for individuals with Broca's and Wernicke's aphasia.*

Qualitative Syntactic Analysis

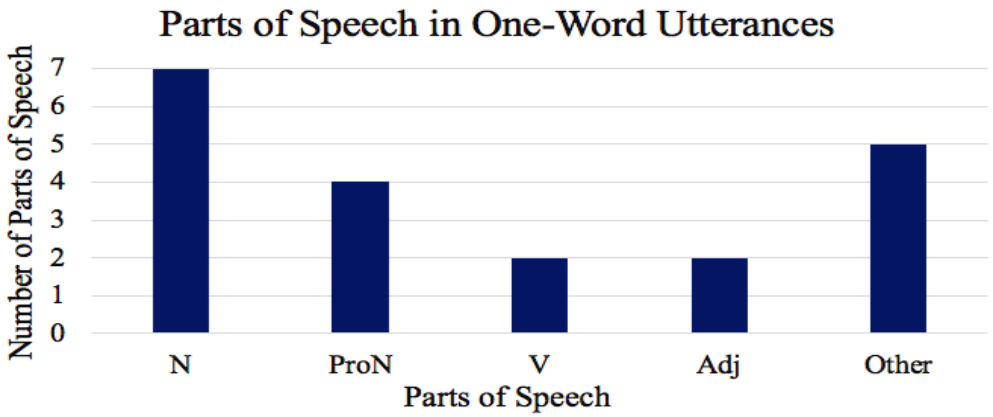


Figure 4*: Graph of the different parts of speech used in the 20 one-word utterances examined for individuals with BA. N = Noun, ProN = Pronoun, V = Verb, Adj = Adjective.*

Figure 4 displays the parts of speech used in these one-word utterances. In the one-word utterances of individuals with BA, the most common part of speech used was a noun (7), followed by the other category (5), and pronouns (4).

Figure 5 illustrates the different syntactic structures used by both groups in their three-word productions. In the three-word utterances of individuals with BA, the most common sentence structure was a subject + verb phrase (9), while for individuals with WA, the most common structures were subject + verb phrase + object (5) and subject + verb phrase (5).

BA		Sub	VP	Ob	Adj	PP	Quot	Other
1	Sub+VP	■	■					
2	VP+Ob		■	■				
3	Onom							■
4	Sub+VP	■	■					
5	Sub+VP	■	■					
6	VP		■					
7	Other+Onom							■
8	Sub+VP	■	■					
9	S+Adj	■			■			
10	S	■						
11	S+Other	■						■
12	Ques							■
13	Sub+VP	■	■					
14	Sub+Quot	■					■	
15	Exclam							■
16	Sub+VP	■	■					
17	Sub+VP	■	■					
18	Other+Quot						■	■
19	Sub+VP	■	■					
20	Sub+VP	■	■					
WA		**Sub**	**VP**	**Ob**	**Adj**	**PP**	**Quot**	**Other**
1	VP+Ob		■	■				
2	Sub+VP+Ob	■	■	■				
3	Sub+VP+Onom	■	■					■
4	Sub+PP	■				■		
5	Sub	■						
6	Sub+VP	■	■					
7	VP+Ob		■	■				
8	Sub+VP+Ob	■	■	■				
9	Sub+VP+Ob	■	■	■				
10	Sub+VP	■	■					
11	Adj				■			
12	Sub+VP	■	■					
13	Exclam							■
14	Sub+VP+Ob	■	■	■				
15	Sub+VP	■	■					
16	Sub+VP+Adj	■	■		■			
17	Sub+VP+Adj	■	■		■			
18	VP+Ob		■	■				
19	Sub+VP+Ob	■	■	■				
20	Sub+VP	■	■					

Figure 5: *The syntactic structures and features of three-word utterances from individuals with BA and WA. Sub = Subject Noun Phrase, VP = Verb Phrase, Ob = Object Noun Phrase, Adj = Adjective Phrase, PP = Prepositional Phrase, Quot = Embedded Quotation.*

Figure 6 demonstrates the different syntactic features used in individuals with BA and WA's three-word utterances. For both groups, the most common syntactic features used in the

three-word utterances were subject phrases (10 for BA, 15 for WA) and verb phrases (11 for BA, and 16 for WA). Individuals with Wernicke's aphasia used more object phrases (8) than individuals with Broca's aphasia (1); however, individuals with Broca's aphasia used more other structures (7) and embedded quotes (2) than individuals with Wernicke's aphasia (2 and 0, respectively).

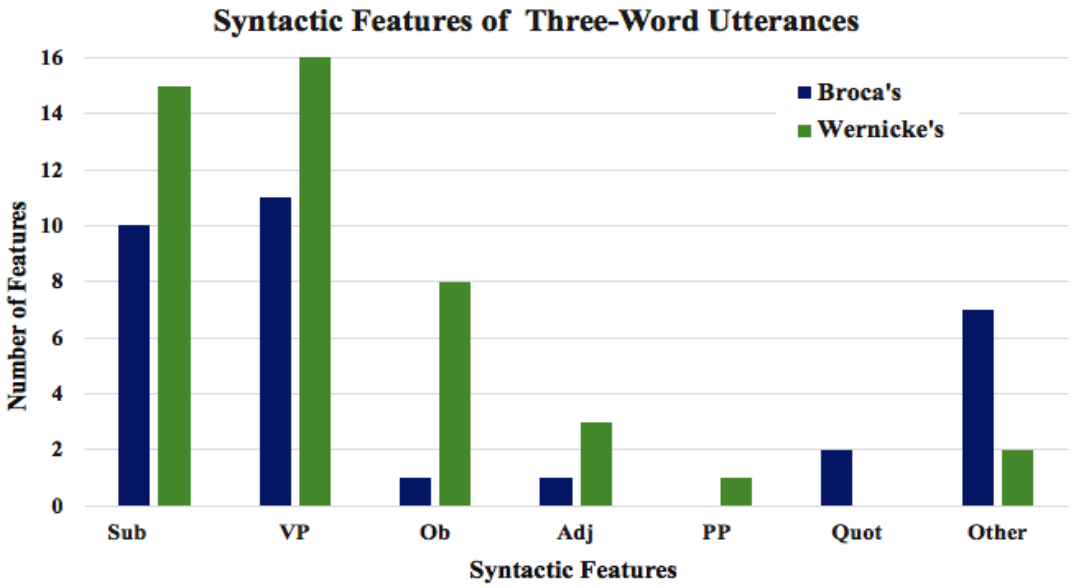
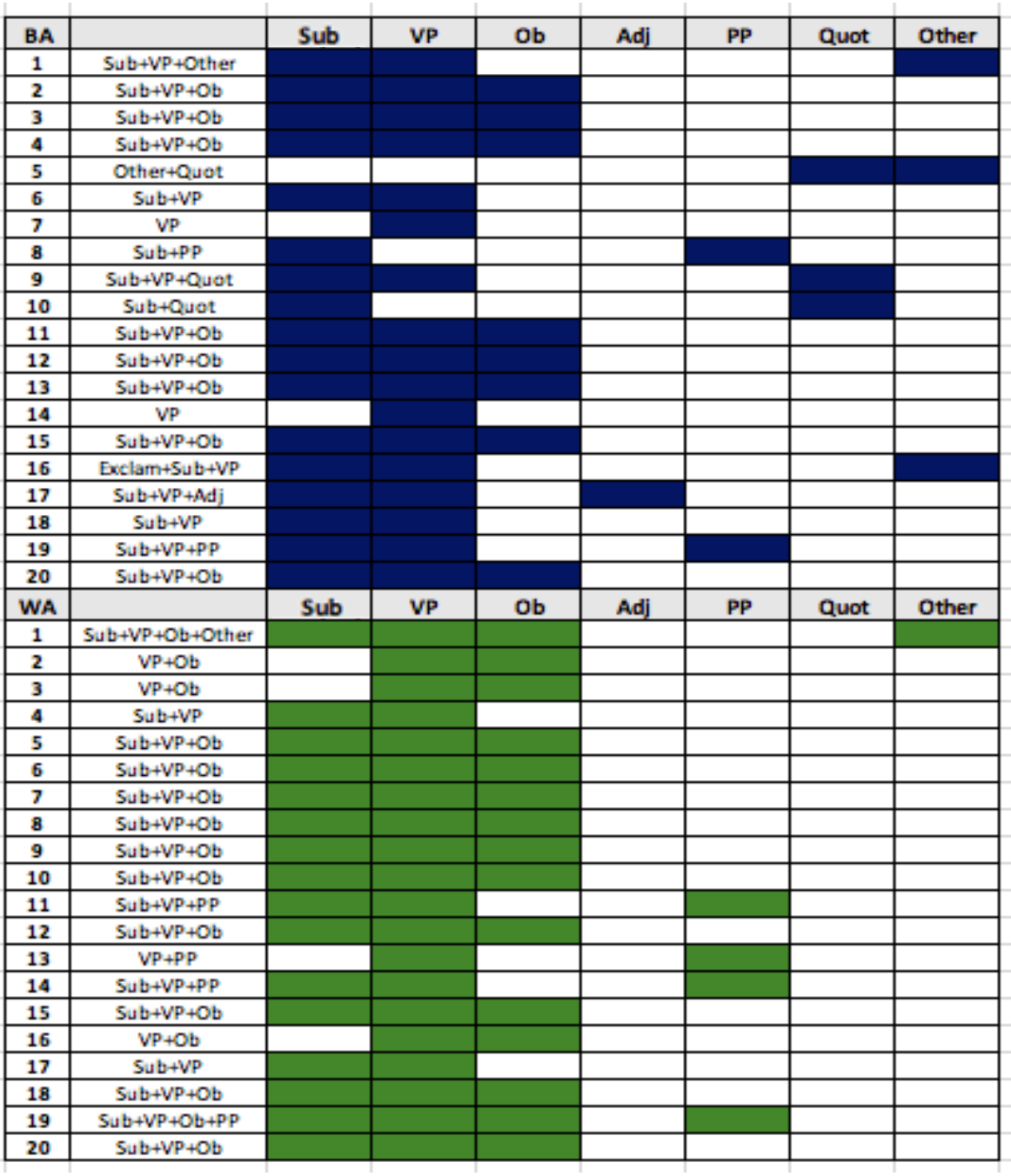


***Figure 6**: Graph of syntactic features used in the three-word utterances of individuals with BA and WA. Sub = Subject Noun Phrase, VP = Verb Phrase, Ob = Object Noun Phrase, Adj = Adjective Phrase, PP = Prepositional Phrase, Quot = Embedded Quotation.*

Figure 7 displays the different syntactic structures used by individuals with Broca's and Wernicke's aphasia in their five-word productions. For both groups, the most frequently used sentence structure in the five-word utterances was subject + verb phrase + object (8 for BA, 10 for WA).



BA		Sub	VP	Ob	Adj	PP	Quot	Other
1	Sub+VP+Other	■	■					■
2	Sub+VP+Ob	■	■	■				
3	Sub+VP+Ob	■	■	■				
4	Sub+VP+Ob	■	■	■				
5	Other+Quot						■	■
6	Sub+VP	■	■					
7	VP		■					
8	Sub+PP	■				■		
9	Sub+VP+Quot	■	■				■	
10	Sub+Quot	■					■	
11	Sub+VP+Ob	■	■	■				
12	Sub+VP+Ob	■	■	■				
13	Sub+VP+Ob	■	■	■				
14	VP		■					
15	Sub+VP+Ob	■	■	■				
16	Exclam+Sub+VP	■	■					■
17	Sub+VP+Adj	■	■		■			
18	Sub+VP	■	■					
19	Sub+VP+PP	■	■			■		
20	Sub+VP+Ob	■	■	■				
WA		**Sub**	**VP**	**Ob**	**Adj**	**PP**	**Quot**	**Other**
1	Sub+VP+Ob+Other	■	■	■				■
2	VP+Ob		■	■				
3	VP+Ob		■	■				
4	Sub+VP	■	■					
5	Sub+VP+Ob	■	■	■				
6	Sub+VP+Ob	■	■	■				
7	Sub+VP+Ob	■	■	■				
8	Sub+VP+Ob	■	■	■				
9	Sub+VP+Ob	■	■	■				
10	Sub+VP+Ob	■	■	■				
11	Sub+VP+PP	■	■			■		
12	Sub+VP+Ob	■	■	■				
13	VP+PP		■			■		
14	Sub+VP+PP	■	■			■		
15	Sub+VP+Ob	■	■	■				
16	VP+Ob		■	■				
17	Sub+VP	■	■					
18	Sub+VP+Ob	■	■	■				
19	Sub+VP+Ob+PP	■	■	■		■		
20	Sub+VP+Ob	■	■	■				

Figure 7*: The syntactic structures and features of five-word utterances from individuals with BA and WA. Sub = Subject Noun Phrase, VP = Verb Phrase, Ob = Object Noun Phrase, Adj = Adjective Phrase, PP = Prepositional Phrase, Quot = Embedded Quotation.*

Figure 8 demonstrates the different syntactic features used in individuals with BA and WA's five-word utterances. Similar to the three-word utterances, the most common syntactic

features were subject phrases (17 for BA, 16 for WA) and verb phrases (17 for BA, 20 for WA). Additionally, individuals with Wernicke's aphasia used object phrases (15) and prepositional phrases (4) more frequently than individuals with Broca's aphasia (8 and 2, respectively). Embedded quotations and other structures were used more by individuals with Broca's aphasia (3 and 3, respectively) compared to individuals with Wernicke's aphasia (0 and 1, respectively).

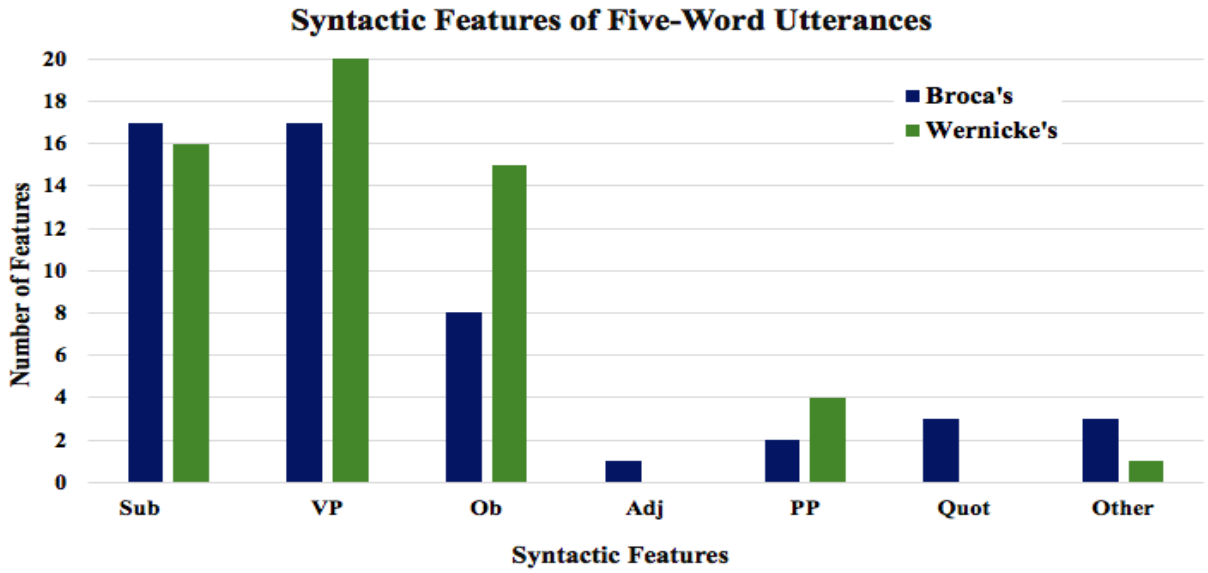


***Figure 8**: Graph of syntactic features used in the three-word utterances of individuals with BA and WA. Sub = Subject Noun Phrase, VP = Verb Phrase, Ob = Object Noun Phrase, Adj = Adjective Phrase, PP = Prepositional Phrase, Quot = Embedded Quotation.*

The findings that individuals with WA produce fewer grammatical errors and more often incorporate syntactic features in their utterances seem to suggest that grammar is preserved in individuals with Wernicke's aphasia. Thus, to more closely investigate the grammatical abilities of individuals with WA, we explored the syntax of some of their longer, more paragrammatic utterances. We found that individuals frequently embedded subordinating clauses in their productions. Sometimes individuals were able to embed subordinate clauses in a grammatically appropriate way, as in the utterance, "As they get older the two girls have decided they are going

to go talk about this man who looks like he is having /secherl/ get to meet other people." However, individuals often embedded subordinate clauses in a way that resulted in jumbled syntax. For instance, in the utterances, "There is always a woman talking about what is going on with people that she would like to do certain things," and, "The young female was taken like a cold church closed churched from the uptaken through as / kʌplid/ as the female did," the multiple embedded subordinate clauses confuse the syntax and make the sentence difficult to understand.

Discussion

This study aimed to investigate the syntactic patterns of individuals with Broca's and Wernicke's aphasia to better understand the disorders of agrammatism and paragrammatism. This was done by comparing utterance-level and word-level errors, the most common length of utterances, and the types of syntactic components and structures used by individuals with Broca's and Wernicke's aphasia.

In short, we found that individuals with Broca's aphasia were almost twice as likely to produce grammatical errors, even though, on average, individuals with Wernicke's aphasia produced utterances that were more than twice as long. Individuals with Broca's aphasia most often produced only one-word or three-word utterances, while individuals with Wernicke's aphasia's most typical utterance length was five words. From our qualitative analysis, we found that individuals with Wernicke's aphasia more often used syntactic elements like objects and prepositional phrases, while individuals with Broca's aphasia relied more on embedded quotations and other elements (e.g., counting, exclamations, onomatopoeia) to increase the length of their utterances.

Utterance-Level Errors

When considering utterance-level errors as a proportion of total utterances, we found that only two types of errors had statistically significant group differences: empty speech and grammatical errors. The higher proportion of empty speech utterances for individuals with Wernicke's aphasia was not surprising, given that a characteristic of Wernicke's aphasia is fluent speech that lacks meaning. Conversely, individuals with Broca's aphasia often have a telegraphic style of speaking, with only the most important content words present. This was evident in the

current study, in the finding that individuals with Broca's aphasia produced double the proportion of grammatical errors compared to individuals with Wernicke's aphasia.

Our findings on grammatical errors suggest the agrammatic deficits that are present in individuals with Broca's aphasia may more severely disrupt their grammatical abilities than the paragrammatic deficits that are present in Wernicke's aphasia. Within the coding scheme of utterance-level errors, the [+gram] code was used simply to indicate the presence of any errors rendering the utterance ungrammatical. Consequently, the coding did not specify the type of grammatical error, so both agrammatic and paragrammatic errors were coded the same. Because individuals with Broca's aphasia produced a higher proportion of grammatical errors, it seems that agrammatism may cause more severe disruptions to individuals' grammatical abilities than paragrammatism. Individuals with Broca's aphasia and agrammatism may only be able to produce fragments and simple utterances that contain the content words of their message. Without the critical smaller grammatical pieces of language present in their utterances, it is not surprising that individuals are less able to produce grammatically correct utterances. When interpreting these findings, the number of individuals in each group with the associated grammatical disorders needs to be considered. That is, how many individuals in the BA group had agrammatism and how many individuals in the WA group had paragrammatism. It is likely that most, if not all, individuals with Broca's aphasia also had agrammatism, but less likely that there were a high number of individuals with Wernicke's aphasia and paragrammatism. The higher proportion of grammatical errors, therefore, could also be the result of having more individuals with agrammatism than paragrammatism in our sample.

Word-Level Errors

Individuals with BA produced a higher proportion of all word-level errors, except for semantic errors, where both groups' proportions were similar, and unrelated errors, where individuals with WA had a higher proportion. However, the only statistically significant group difference was found for phonological non-word errors. Phonological paraphasias are common among individuals with Broca's aphasia and Broca's aphasia is likely to co-occur with motor speech disorders, particularly apraxia of speech (Basilakos & Fridriksson, 2022). For reference, in our BA group, 16 individuals also had apraxia of speech, compared to only one individual in the WA group. It is likely, then, that individuals with BA were producing more of these phonological errors as a result of their apraxia. It should be noted that there were three individuals in the BA group that were outliers in terms of their high proportion of phonological non-word errors. Thus, these individuals presumably skewed the mean, and it is possible that including more individuals, or excluding these individuals, could have reduced the significance of group differences in phonological non-word errors.

Utterance Length

Not surprisingly, individuals with Wernicke's aphasia produced more words and utterances in their language samples than individuals with Broca's aphasia. Furthermore, individuals with Wernicke's aphasia were also found to use significantly more words per utterance than individuals with Broca's aphasia. The individuals in the Broca's aphasia group most often generated one-word or three-word utterances, while the individuals in the Wernicke's aphasia group most often formed five-word utterances. These results make sense, given that Wernicke's aphasia is a fluent aphasia type where individuals typically do not struggle to produce language output relative to individuals with non-fluent Broca's aphasia.

Qualitative Syntactic Analysis

The finding that one-word and three-word utterances were most frequently produced by individuals with Broca's aphasia relates to the previous discussion of grammatical difficulties for individuals with agrammatic deficits, for it can be very difficult to produce an utterance that is grammatical if it only contains one or three words. These productions were often incomplete, leaving out necessary grammatical markers and function words, rendering the utterances ungrammatical.

In the one-word utterances of individuals with Broca's aphasia, the most frequent part of speech used was a noun. Because nouns are content words, it is not surprising that individuals with BA produced them most frequently, for the speech of these individuals takes on a telegraphic style. Results are also consistent with studies showing that individuals with aphasia struggle more with verb processing in language production and comprehension relative to the processing of nouns (Alyahya, et al., 2018).

Individuals' three-and five-word productions yielded more insight into the specific syntactic structures and features used by individuals with Broca's and Wernicke's aphasia. First, we found that individuals with WA more commonly included objects and prepositional phrases in their utterances than individuals with BA, whereas individuals with BA relied more on using features like embedded quotes and different structures, like exclamations, counting, and onomatopoeias, which we labeled as "other". These findings suggest that in the face of their impairments, individuals with BA embed quotations and include other structures in their productions as a way to convey their messages, instead of attaching more grammatical syntactic features like prepositional phrases. It appears that individuals' agrammatic deficits affected their ability to incorporate these common syntactic structures into their utterances.

Conversely, it seems that individuals with Wernicke's aphasia were more able to generate utterances using appropriate syntactic features as the length of their utterances increased. However, they did not always do so appropriately, as was seen by examining their longer utterances. As the length of their utterances increased, individuals embedded more subordinate clauses within their productions. While some individuals did this correctly, often this embedding led to paragrammatic utterances with confused syntax. These longer utterances better demonstrate the paragrammatic deficits of individuals with WA.

Limitations

The findings of this study should be interpreted with its limitations in mind. Our first limitation relates to the relatively small sample size of both groups. Because each group was comprised of only 20 individuals, the statistical power is low, reducing the generalizability of our findings. Moreover, this study only included language from individuals with WAB-AQ scores that were moderate to severe. It is unknown, therefore, if these findings are representative of individuals with varying aphasia severities, or if the group differences we found would have been different had we included individuals with very severe or mild aphasia.

It should also be noted that our qualitative analysis was limited by its lack of specificity; that is, we only examined the presence of different syntactic components, not the grammaticality with which they were used. For example, we found that individuals with WA used more features like prepositions and objects, but we did not explore how often they used these elements grammatically. The findings from our qualitative analysis helped us to understand the syntactic abilities of the participants, along with the elements they included to increase the length of their utterances, but do not expressly tell us about individuals' grammatical abilities.

Conclusion

This study sought to explore the grammatical and syntactic abilities of individuals with Broca's and Wernicke's aphasia in an attempt to better understand agrammatism and paragrammatism, respectively. Our results supplied us with information about the language characteristics of individuals with these grammatical disorders. First, we found that individuals with BA produced a higher proportion of grammatical errors, per utterance, than individuals with WA. Second, we discovered that in their three-and-five-word utterances, individuals with BA less often included syntactic elements like objects and prepositional phrases, compared to individuals with WA, and instead used structures like embedded quotations, onomatopoeias, exclamations, and counting as their utterances increased in length. The use of these less typical syntactic elements, particularly the pseudo-grammatical "other" structures, may also reflect agrammatic deficits in individuals with aphasia. The longer utterances from individuals with WA better demonstrated their paragrammatic deficits, specifically, the excessive, and often incorrect, embedding of subordinate clauses that frequently resulted in jumbled syntax.

The findings from our study support the idea from Matchin and Hickok (2020) and Matchin et al. (2020) that agrammatism and paragrammatism are distinct disorders. We found different patterns of speech output for individuals with Broca's aphasia (and agrammatism), and Wernicke's aphasia (and paragrammatism) in terms of both proportion of grammatical errors and syntactic abilities. Future studies should seek to more specifically code and examine the syntactic features and errors present in the language of those with BA and WA. More research still needs to be done to further describe the patterns of agrammatism and paragrammatism and resolve the debate about the status of these disorders as separate. Developing a better understanding of

agrammatism and paragrammatism will lead to the more effective diagnosis and treatment of these disorders.

Acknowledgements

This project received summer funding from the Iowa Center for Research by Undergraduates. I would like to thank Dr. Jean Gordon for helping me design and conduct this project along with Alexis Mansour and Abby Wickre for helping code core utterances. I would also like to extend my gratitude to the creators and maintainers of AphasiaBank, in addition to the individuals who consented to their data being stored in the database.

References

Alexander, M. P., & Hillis, A. E. (2008). Aphasia. *Handbook of Clinical Neurology*, *88*, 287-309.

Alyahya, R. S., Halai, A. D., Conroy, P., & Ralph, M. A. L. (2018). Noun and verb processing in aphasia: Behavioural profiles and neural correlates. *NeuroImage: Clinical*, *18*, 215-230.

American Speech-Language-Hearing Association (n.d.). *Aphasia* (Practice Portal). Retrieved March 31, 2021, from https://www.asha.org/Practice-Portal/Clinical-Topics/Aphasia/.

Basilakos, A., & Fridriksson, J. (2022). Types of motor speech impairments associated with neurologic diseases. *Handbook of Clinical Neurology*, *185*, 71-79.

Bleser, R. D. (1987). From agrammatism to paragrammatism: German aphasiological traditions and grammatical disturbances. *Cognitive Neuropsychology*, *4*(2), 187-256.

Butterworth, B. (1994). Disorders of sentence production. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *346*(1315), 55-61.

Butterworth, B., & Howard, D. (1987). Paragrammatisms. *Cognition*, *26*(1), 1-37.

Ellis, C., & Urban, S. (2016). Age and aphasia: a review of presence, type, recovery and clinical outcomes. *Topics in Stroke Rehabilitation*, *23*(6), 430-439.

Fergadiotis, G., & Wright, H. H. (2011). Lexical diversity for adults with and without aphasia across discourse elicitation tasks. *Aphasiology*, *25*(11), 1414-1430.

Kertesz, A. (1982). *Western Aphasia Battery*. Grune & Stratton.

Kleist, K. (1914). Aphasie und geisteskrankheit. *Münchener Medizinische Wochenschrift*, *61*, 8-12.

Kleist, K. (1916). Uber Leitungsaphasie und die grammatischen Storung. *Mschr. Psychiatr. Neural*, *40*(1), 18-199.

Kleist, K. (1934). Kriegsverletzungen des Gehirns in ihrer Bedeutung fur die Hirnlokalisation und Hirnpathologie. *Handbuch der artzlichen Erfahrungen im Weltkriege 1914/1918 band IV*, 343- 1390.

Kolk, H., & Heeschen, C. (1992). Agrammatism, paragrammatism and the management of language. *Language and Cognitive Processes*, *7*(2), 89-129.

Kolk, H. H., & Van Grunsven, M. M. (1985). Agrammatism as a variable phenomenon. *Cognitive Neuropsychology*, *2*(4), 347-384.

Le, H., & Lui, M.Y. Aphasia. (Updated 2021). *StatPearls*. StatPearls Publishing.

MacWhinney, B. (2000). The CHILDES Project: Tools for Analyzing Talk. 3rd Edition. Mahwah, NJ: Lawrence Erlbaum Associates.

MacWhinney, B., Fromm, D., Forbes, M. & Holland, A. (2011). AphasiaBank: Methods for studying discourse. *Aphasiology, 25,*1286-1307.

Matchin, W., Basilakos, A., Stark, B. C., den Ouden, D. B., Fridriksson, J., & Hickok, G. (2020). Agrammatism and paragrammatism: a cortical double dissociation revealed by lesion-symptom mapping. *Neurobiology of Language*, *1*(2), 208-225.

Matchin, W., & Hickok, G. (2020). The cortical organization of syntax. *Cerebral Cortex*, *30*(3), 1481- 1498.

Saffran, E. M., Schwartz, M. F., & Marin, O. S. (1980). Evidence from aphasia: Isolating the components of a production model. *Language Production*, *1*, 221-241.

Yagata, S. A., Yen, M., McCarron, A., Bautista, A., Lamair-Orosco, G., & Wilson, S. M. (2017). Rapid recovery from aphasia after infarction of Wernicke's area. *Aphasiology*, *31*(8), 951-980.