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Prosodic Characteristics of People With Moderate Broca's Aphasia: Measures of Pitch and Intensity

Morgan Smith Lambert
Brigham Young University

Prosodic Characteristics of People With Moderate Broca's

Aphasia: Measures of Pitch and Intensity

Morgan Lambert

A thesis submitted to the faculty of
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Master of Science

Shawn L. Nissen, Chair
Connie Summers
Christopher Dromey

Department of Communication Disorders

Brigham Young University

ABSTRACT

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Morgan Smith Lambert
Department of Communication Disorders, BYU
Master of Science

Aphasia is an acquired neurogenic language disorder commonly treated by speech language pathologists (SLPs). People with aphasia (PWA) experience various language deficits which impact their ability to effectively communicate with their environment. One of these deficits which impacts individuals with non-fluent aphasia is dysprosody. The purpose of this study is to acoustically evaluate the pitch and intensity of individuals with moderate Broca's aphasia along with age and gender matched control participants across a variety of task types in order to help SLPs better understand how to effectively assess and treat prosody in PWA. This study is an extension of Pickard (2025) study and while the groups of speakers evaluated and the acoustic analyses are similar between the two studies, the specific recordings examined as well as the resulting findings are independent. This study included 16 individuals with moderate non-fluent Broca's aphasia and 16 neurologically healthy control subjects of similar ages and genders. Speech samples from the 32 participants were sourced from the AphasiaBank database and included samples across the following task types: picture description, personal narrative, personal interview, and story retell. A repeated measures using Analysis of Variance (ANOVA) was calculated to determine potential differences in prosodic pitch and intensity patterns across task type. Differences as a function of aphasia status were also investigated. Results find significant differences across speech task for the dependent measures of intensity range and intensity variability. However, no interaction effects were found as a function of neurological status. Regarding pitch measures, pitch range was found to differ significantly as a function of speech task type and the aphasia status of the speaker. No other significant main effects or interactions were found for pitch or intensity as a function of speech task type or neurological status. Overall, this study contributes to the growing research on dysprosody in PWA. Further research is warranted in order to confirm the findings of the study and enhance clinical understanding of dysprosody in PWA to more effectively approach treatment and assessment of non-fluent aphasia.

Keywords: aphasia, prosody, Broca's aphasia, non-fluent aphasia, pitch, intensity

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DESCRIPTION OF THESIS STRUCTURE

This thesis, *Prosodic Characteristics of People With Moderate Broca's Aphasia: Measures of Pitch and Intensity,* is part of a larger study exploring the impact of cognitive pause on speech communication in persons with Aphasia. Portions of this thesis may be submitted for publication, with the thesis author being included in the list of contributing coauthors. An annotated bibliography is provided in Appendix A, and the Institutional Review Board approval of study protocols and consent form is provided in Appendix B.

Introduction

Language is a fundamental aspect of the human experience as it is the medium through which we express thoughts, convey emotions, interact with others and develop relationships. Dependent upon their clinical setting, speech language pathologists (SLPs) provide assessments, diagnoses and appropriate treatment for individuals who experience difficulty communicating as a result of acquired language disorders. One of these language disorders is aphasia, an acquired neurogenic language disorder in which an impairment of language expression and/or reception occurs as a result of injury to the brain via trauma or neurodegenerative disease (National Institute on Deafness and Other Communication Disorders, 2017).

Aphasia inhibits the ability to process, comprehend, and produce language across all modalities which can lead to deficits in the production and perception of verbal expression, auditory comprehension as well as reading and writing abilities (Le & Lui, 2023; Leung et al., 2016). As speech and its suprasegmental characteristics are essential in effectively communicating with conversational partners, people with aphasia (PWA) often experience increased difficulty in this communication process. Not only do these communicative deficits impact the efficiency and efficacy with which PWA communicate specifically, but their quality of life generally as well.

The considerable psychosocial consequences associated with aphasia have been well documented and include significant emotional and social impacts such as, increased self-consciousness, feelings of "linguistic anxiety," experiences of social isolation, and loss of friends due to associated communication difficulties impeding communicative effectiveness (Code & Herrmann, 2003; Parr, 2007). Furthermore, PWA may also experience heightened instances of negative emotions such as anger and frustration as well as symptoms of depression. Likely because of their language disorder, the incidence of depression after aphasia is even higher than in stroke survivors who do not have aphasia (Kauhanen et al., 2000). These communication and emotional difficulties experienced by PWA may also decrease the frequency of their social participation and interactions with their community. A study conducted by Dalemans et al. (2010) reported PWA to be less involved in social activities due in part to concerns with being a burden on others, hindering group interactions due to less effective communication skills, and concerns that unfamiliar communication partners will not be readily accommodating to their needs.

While there are various communication challenges impacting PWA, this study will focus on dysprosody. While individuals with aphasia often have challenges with formulating what they say, their lack of prosody or appropriate emotion when communicating also impacts the meaning behind their words and can alter their ability to participate in meaningful communication and develop relationships. This is not unique to people with aphasia. Similarly, individuals with apraxia of speech, a neurogenic motor speech programming disorder often seen in conjunction with non-fluent aphasia, can experience challenges in life participation activities as well as relationship development and maintenance due to deficits related to prosody. This study evaluates prosodic elements produced by individuals with non-fluent aphasia in order to increase understanding of intervention techniques and considerations that will best serve these populations and support the relationships, communication and overall quality of life of PWA.

Causes, Characteristics, and Subtypes of Aphasia

Based on recent data, approximately one in 272 individuals in the United States are currently diagnosed with aphasia, with an incidence rate of 180,00 new cases per year (Le & Lui, 2023). There are a variety of causes of aphasia including traumatic brain injury (TBI), brain tumor, as well as neurodegenerative diseases such as Alzheimer's disease. However, the most commonly attributed etiology of aphasia is a stroke or cerebrovascular accident (CVA) in which blood flow to language centers of the brain is halted through either an ischemic or hemorrhagic event (Lee et al., 2021). Approximately one-third of individuals who experience a CVA acquire some form of aphasia, resulting in impairment to fundamental elements of their language system including but not limited to phonology, morphology, semantics and pragmatics (Sheppard & Sebastian, 2020). The severity and nature of these specific impairments are dependent upon the location and extent of damage that occurs during the CVA. While there are common characteristics exhibited across the majority of PWA, such as word finding difficulties, aphasia can generally be categorized into two broad types: fluent and non-fluent. Type of aphasia is determined during assessment based on the location of injury as well as the language characteristics exhibited by the individual such as speech fluency, auditory comprehension, generative naming, and repetition.

Fluent subtypes of aphasia, such as Wernicke's aphasia, are generally the result of temporal lobe lesions, and typically exhibit fluent verbal production with relatively intact prosody, although they often combine novel and other nonmeaningful words with real words which leads to sentences lacking semantic meaning to the listener (i.e., neologisms and jargon) (Sheppard & Sebastian, 2020). Furthermore, individuals with fluent subtypes of aphasia can demonstrate a lack of awareness of their errors as well as varying degrees of impairment in auditory comprehension. People with fluent aphasia demonstrate few hesitations with language generation, although those productions frequently lack meaning (Sheppard & Sebastian, 2020).

Non-fluent types of aphasia, however, are typically the results of tissue damage in the frontal lobe, and result in effortful speech in which fewer words/utterances are generated during communication attempts compared to individuals without aphasia. This is demonstrated by elements of impaired prosody, word-finding deficits, agrammatism, as well as decreased phrase length and mean length of utterance (Fraser et al., 2014). People with non-fluent types of aphasia tend to understand language better than they produce it, with their language comprehension remaining relatively intact and primary deficits being related to language expression.

One common type of non-fluent aphasia which this study will be focusing on is Broca's aphasia, which can occur after damage to Broca's Area located in the inferior posterior portion of the frontal lobe. Broca's aphasia is characterized by deficits in expressive language including halting, effortful speech with frequent pauses and overall reduced phrase length. People with Broca's aphasia tend to produce short and simple phrases consisting of content words, tend not to produce complex grammatical constructions, and frequently omit function words such as prepositions (i.e. telegraphic speech). Significant word finding difficulties also result in frequent use of circumlocutions during speech.

Additionally, due to the location of the lesions, individuals with non-fluent aphasia also commonly present with apraxia of speech (AOS) which is a neurogenic motor speech programming disorder that impacts an individual's ability to sequence the sensorimotor commands needed to produce speech. Although reliable data collection is challenging, research has indicated that the co-occurrence of AOS to be approximately 81% for aphasia, 29–47% for dysarthria, and 48–75% for nonverbal oral apraxia (Moser et al., 2016). AOS is characterized by core deficits in the speech subsystems of articulation and prosody as opposed to deficits related to language as is the case with aphasia. Some of the most commonly seen deficits of AOS are inconsistent articulation errors, phonemic distortions, atypical prosody seen through reduced rate of speech, syllable segregation and equal stress patterns. Other behaviors that are often present in

AOS include speech initiation difficulties, articulatory groping, perseverative errors, and increased errors with increased word length and complexity (Mauszycki & Wambaugh, 2006).

In addition to language production challenges associated with aphasia and the commonly present concomitant condition of AOS, individuals with Broca's aphasia frequently experience dysprosody, a disruption in the normal rhythm and pitch of speech. PWA experience difficulty comprehending and producing the suprasegmental and emotional features of language (Samuel et al., 1998). This typically manifests as monotone or robotic speech patterns where the natural intonation and prosodic variations are significantly diminished. This reduction in prosody can affect the emotional expressiveness and natural flow of speech, further impeding effective communication for PWA.

Prosody

Prosody is a broad term encompassing a range of suprasegmental speech components that add linguistic and nonlinguistic meaning to verbal communication (Walker et al., 2009). This meaning is communicated through changes to the rhythm, pitch, intonation, and vocal quality of a speaker which serve to convey meaning beyond the literal content of words. It plays a crucial role in the interpretation and understanding of spoken language by providing cues about emotional tone and conversational intent. The methods in which one uses prosody to convey meaning varies from one speaker to another, and the same prosodic feature can be used for a variety of meanings. For instance, variations in pitch and stress help differentiate between questions and statements, while changes in intonation can indicate emphasis or convey sarcasm. Prosody includes elements of communication related not just to what a person says but rather how it is said. Prosodic elements of speech include tempo, pitch/intonation, emphasis, and speech pause. Tempo refers to the rate and rhythm of speech. Sentence-level pitch, or intonation, “conveys verbal information at the sentence or phrase level” (Seddoh, 2000) and can signal the function of a person’s utterance. Stress, or emphasis, functions in a sentence by adding prominence to particular words, therefore affecting the overall meaning of an utterance. Stress can be marked by the duration, amplitude, and fundamental frequency of segments of a person’s speech (Walker et al., 2009). Elements of prosody provide both understanding of and the ability to communicate to others linguistic distinctions and emotional affect (Loveall et al., 2021). Speakers use their prosody to create communication that is more effective, likable, and easier to comprehend. Prosodic elements of speech in a spoken utterance make it possible for listeners to correctly determine the intended meaning of the speaker. Studies show variation in speed, intensity, pitch, and duration signal the beginning and end of speech units including syllables, words, phrases, and sentences (Shriberg et al., 2013). Similarly, prosodic features of spoken language appropriately signal shifts in topic of conversation. Knowing when a conversation is changing versus when it is being maintained is important to effective exchanges and comprehension. As stated, PWA also experience deficits in utilizing prosody, which drastically impacts their communicative effectiveness in the aforementioned areas. Challenges related to impaired prosody may contribute to the feelings of social isolation experienced by people with Broca’s aphasia as well as their difficulties in effectively expressing their thoughts and emotions as well as establishing and maintaining relationships.

Dysprosody in People With Aphasia

People with aphasia commonly present with altered prosody compared to the general population in linguistic contexts. A study conducted by Gavarró and Salmons (2013) demonstrated that individuals with Broca’s aphasia identified prosodic elements of speech with lower accuracy compared to neurologically healthy individuals when asked to determine whether pairs of spoken sentences were identical or different in terms of intonation (89.1% accuracy compared to 95.6% accuracy of the control group). This paper will focus primarily on dysprosody in people with non-fluent aphasia, specifically in relation to the prosodic elements of pitch and intensity across various speech task types.

Pitch and Intensity

For the purposes of this study, the term pitch will be used to refer to fundamental frequency and not the perceptual characteristics. In typical speech, pitch serves as a crucial element of both intonation and lexical stress, allowing speakers to highlight key information, convey emotion and signal sentence type as well as allowing listeners to accurately identify this information. Several studies have found that speakers with non-fluent aphasia often display a markedly reduced pitch range and a diminished fundamental frequency variability compared to non-aphasic speakers, resulting in speech that is perceptually monotone or flattened. For example, a study by Walker et al. (2009) had such findings indicating that the participants with left hemisphere dysfunction demonstrated reduced mean fundamental frequency compared to the control group when given 10 pairs of two-syllable words with contrasting stress patterns. Furthermore, this study found greater variance in the amplitude of stress patterns during the task compared to the control group. Overall, this flattening of pitch and diminished fundamental frequency can impair not only the expressive capabilities of the speakers but also the listener's ability to correctly identify and interpret syntactic and emotional cues as their speech is lacking some of the natural rise and fall of pitch that neurologically healthy speakers use. Furthermore, this reduced pitch modulation is evident not just in single words but also at sentence boundaries in which falling intonation in declaratives and rising intonation in questions may be absent or misused. Acoustic analyses in these and other studies have shown that speakers with non-fluent aphasia often produce speech with misplaced or inconsistent stress patterns partially due to reduced control over pitch modulation. This disruption in stress patterns can reduce intelligibility, especially in multisyllabic words and complex utterances. These challenges in modulating pitch can result in speech that lacks appropriate emphasis or places stress on unintended syllables, thus contributing to listener confusion.

Intensity, commonly perceived as speech loudness, is an acoustic feature of speech that plays a critical role in effective communication. Not only does it contribute to the audibility of speech, but it works alongside pitch to convey emphasis, emotion, speaker intent as well as signal stress patterns and sentence types. For example, stressed syllables typically have a greater intensity than unstressed syllables, helping listeners distinguish between similar sounding words. These variances in intensity are essential for speech intelligibility and naturalness, particularly in contexts in which linguistic content may be ambiguous. While in typical speakers, intensity is modulated naturally to reflect these elements, individuals with non-fluent types of aphasia may exhibit reduced intensity variation and lower overall speech amplitude.

A literature review conducted by Zipse et al. (2025) regarding prosody in individuals with agrammatic aphasia found limited evidence available on whether amplitude is preserved as a prosodic cue in non-fluent aphasia. While some studies found evidence for preserved and compensatory use of intensity (Baqué, 2017) others found that speakers with agrammatic aphasia did not vary intensity across syllables in a typical way (Balan & Gandour, 1999). The Balan and Gandour (1999) study reported that participants with agrammatic aphasia did not use intensity to signal syllable stress and showed less syllable-to-syllable intensity variation compared to controls, people with right-hemisphere damage, and people with fluent aphasia. Furthermore, a study by Vuković et al. (2012) supports these findings as its study analyzed acoustic and perceptual measures related to speech and phonation across 60 males with aphasia (20 with Wernicke's, 20 Broca's, 20 transcortical) and found that individuals with Broca's aphasia exhibited impairments in various acoustic and perceptual measures of phonation including loudness when compared to control speakers. This diminished control over intensity may stem from impaired motor planning, disrupted prosodic processing, or both, resulting in a decreased ability to mark stress appropriately or emphasize key elements of speech. These impairments not only reduce speech naturalness but also affect listener comprehension, as listeners rely on intensity cues to segment speech and interpret meaning.

While the published literature regarding intensity in aphasiac speakers is limited and somewhat variable, the ramifications of impaired speech intensity has been well-documented in other disorders affecting speech such as Parkinson's disease and various types of dysarthria. The lack of, and changes in, intensity associated with these disorders present significant communication challenges. Altered speech intensity often results in reduced intelligibility on the part of the speaker and increased effort on the part of the listener. In Parkinson's disease, hypokinetic dysarthria is commonly characterized by reduced vocal loudness and a limited dynamic range, making it challenging for listeners to perceive stressed syllables or follow prosodic cues (Duffy et al., 2014). In other types of dysarthria, impaired neuromuscular control leads to inconsistent or insufficient modulation of intensity which impairs the clarity and expressiveness of speech. These intensity deficits are a significant challenge as they hinder the speaker's ability to convey affect, emphasize key information, and compete with background noise, which can impact the efficiency and effectiveness of everyday communication. Several therapeutic treatment approaches designed to address these impairments have been developed. For example, the Lee Silverman Voice Treatment is a well-established treatment method to improve vocal loudness and speech intelligibility, particularly in individuals with Parkinson's disease, by encouraging patients to "think loud" and produce speech at a higher volume than normal to combat the hypophonia typically seen in Parkinson's disease (Ramig et al., 2001). The exercises associated with this treatment protocol have been shown to increase vocal loudness, improve speech intelligibility and enhance overall communicative effectiveness in conditions where reduced intensity severely impairs communication.

While the literature on speech intensity changes in non-fluent aphasia is less well-documented, it is reasonable to assume that much like in Parkinson's disease, the reduced pitch variation and decreased intensity found in PWA can result in similar communication challenges. As previously stated, reduced or flattened pitch variation and decreased intensity in people with aphasia can make it difficult to emphasize key words, signal sentence modality, or convey emotion, thereby diminishing overall speech intelligibility (Vuković et al., 2012). Just as reduced speech intensity in Parkinson's disease and dysarthria can lead to communication breakdowns and frustration, similar intensity deficits in aphasia may have a negative impact on the speaker's ability to communicate effectively, thus further compounding the challenges they face when interacting with various communication partners.

Task Type

As this study will be evaluating changes in pitch and intensity in people with Broca's aphasia across task type, it is important to acknowledge the ways in which a speaker's speech changes based on the task type and its associated cognitive load. A person with aphasia has trouble with language processing, which can significantly impact communication in various contexts. These communication challenges may change as a function of different speech task types because different tasks require different levels of language and cognitive processing depending on their complexity.

Speech tasks can generally be categorized as either structured or unstructured. These tasks differ primarily in the level of control, guidance, and support they provide to the speaker. Structured speech refers to speech production in tasks that have a defined format or prompt, like answering specific questions or describing a picture. Unstructured speech on the other hand, refers to speech production in spontaneous conversations or narratives, where there is less control over the topic or structure of the conversation. This involves more spontaneous speech and less constraints by external prompts. These tasks tend to be considered more functional and ecologically valid as they reflect more naturalistic conversation and what a speaker may experience during everyday conversation. Structured tasks can reduce the cognitive demand on the individual with aphasia as they are less reliant on independent language planning and word retrieval. Conversely, unstructured tasks tend to require greater cognitive effort because the individual must independently formulate language, respond to conversational cues and manage the dynamic flow of conversation. They require greater planning, organization and self-regulation on the part of the speaker while structured tasks provide a clear framework and often a clear agenda.

Generally, pitch and intensity in neurologically healthy individuals vary significantly across different speech task types. Studies indicate that habitual pitch is generally higher during unstructured speech tasks compared to structured ones. For instance, in a study related to preschool aged children, Chen et al. (2009) found that children exhibited significantly higher habitual pitch during free play activities compared to structured speech activities. Similarly, a case study conducted by Hunter (2009) found that a child's fundamental frequency was notably higher during unstructured vocalization compared to structured elicited tasks. This variation could be related to how different tasks require different levels of intonation, stress patterns, and modulation of pitch and intensity. In structured speech tasks, such as reading passages or repeating sentences, pitch patterns tend to be more predictable and less variable, as speakers are guided by specific instructions or phrasing. These tasks often involve fewer intonation shifts compared to more natural, spontaneous speech, and any pitch changes are generally used to mark syntactic boundaries or stress key information in a controlled manner. For instance, in a reading task, pitch changes might only occur at sentence boundaries, where rising intonation signals a question or a falling intonation marks a statement. In contrast, unstructured speech tasks, like conversation or storytelling, typically involve a greater range of pitch modulation, as speakers use pitch to convey emotions, emphasize particular words, or indicate changes in discourse structure. In these tasks, pitch tends to be more dynamic and variable, reflecting the speaker's emotional state, conversational context, or the need to signal shifts in topic.

Language performance in people with aphasia can vary depending on the type of speech task being performed, with notable differences between structured and unstructured tasks. A study conducted by Leaman and Edmonds (2021) assessed language in unstructured conversation in people with aphasia compared to a structured narrative task (picture description). While this study primarily evaluates the interrater reliability and test–retest stability of various linguistic measures, it did find preliminary evidence that language production varies for some measures between unstructured conversation and a story narrative. Specifically, some linguistic measures showed strong correlations across conditions, while others did not, indicating that language performance can differ depending on the task type. Alyahya et al. (2020) also highlighted that connected speech performance in non-fluent aphasia differs across structured versus unstructured tasks as well as discourse genres (descriptive via picture description, narrative, and procedural). Connected speech samples across descriptive, narrative, and procedural discourse genres were collected from 46 patients with chronic post-stroke aphasia and 20 neurotypical adults. Content analyses conducted on all connected speech samples indicated that performance differed across discourse genres and between groups. Specifically, storytelling narratives provided higher quantities of content words and lexical diversity compared to composite picture description and procedural discourse. The analyses further revealed that, relative to neurotypical adults, patients with aphasia, both fluent and non-fluent, showed reduction in the quantity of verbal production, lexical diversity, and informativeness across all discourses. In summary, research tends to suggest that language performance in people with non-fluent aphasia varies between structured and unstructured speech tasks, with structured tasks often eliciting better performance compared to unstructured tasks. This could be because structured tasks allow for more predictable and controlled language production. Furthermore, the increased cognitive load associated with unstructured tasks can potentially impact the quality and clarity of speech production in individuals with aphasia, as more resources are able to be allocated there instead of towards cognitive tasks.

Changing speech task type influences the difficulty of the tasks, their subsequent cognitive load and potentially, the degree to which prosodic elements such as pitch and intensity are affected. While there are limited studies specific to prosody comparing pitch and intensity across different task types among people with Broca's aphasia, pitch variations in people with non-fluent/agrammatic primary progressive aphasia have been studied in various speech tasks. A study conducted by Haley et al. (2021) involved 25 participants with primary progressive aphasia including 10 with the non-fluent/agrammatic variant. Speech samples were collected including word repetition, picture description, and story narrative tasks. Acoustic analyses found that measures of distortion frequency, syllable duration, scanning, and, to a limited extent, syllable stress showed greater impairment in the non-fluent/agrammatic variant of PPA compared to other variants. These findings suggest that measures related to pitch variations are more pronounced in “naturalistic” speech tasks. While different from Broca’s aphasia, these findings may also suggest that individuals with non-fluent variants of aphasia may produce variants in speech pitch and intensity compared to other speakers across task types. Although this study provides valuable insights, further research is needed to understand the relationship between task type and pitch/intensity variants in individuals with aphasia.

Purpose of This Study

This study will specifically evaluate the following research questions:

1. Do individuals with moderate non-fluent aphasia demonstrate atypical patterns of prosodic pitch and intensity compared to individuals without aphasia? It is expected that individuals with Broca’s aphasia will demonstrate atypical patterns of prosodic pitch and intensity compared to the neurologically healthy control subjects.

2. Do pitch and intensity patterns change as a function of different speech task types in individuals with non-fluent aphasia compared to neurologically healthy speakers? Based on the review of the literature, it is expected that pitch variability as well as intensity will decrease in tasks that have less context and require greater cognitive effort, such as the personal narrative task.

Method

This study is an extension of previous work by Pickard (2025) which also evaluated the prosodic patterns of people with moderate non-fluent aphasia. The unique contribution of this study is that the methodology used by Pickard to examine the pitch and intensity produced by a group of aphasic and neurologically healthy speakers is being applied to a variety of different speech task types (i.e., personal narrative, personal interview, and picture description) in addition to the story retell data analyzed and reported by Pickard. Thus, the groups of speakers evaluated, and the acoustic analyses are similar between the two studies, however the specific recordings examined as well as the resulting findings are independent.

Participants

This study is part of a collaborative project examining prosodic patterns of speech in people with Broca's aphasia; therefore, it builds upon the research conducted by Pickard (2025) and thus employs similar methodologies. As shown in Table 1, 16 individuals previously diagnosed with moderate non-fluent Broca's aphasia, as well as apraxia of speech, participated in the study. Participant ages spanned from 31.8–78.3 years (M = 55.5), with an even number of individuals who identified as male or female. The speakers' severity of aphasia was determined using the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2006). Their WAB Aphasia Quotient (AQ) scores ranged from 52.5 to 72.8 (M = 61.58). In addition, data was also extracted from the speech recordings of 16 gender-matched neurologically healthy control subjects.

Table 1

Demographic Information for Participants With Moderate Broca's Aphasia

Study	Subject	Gender	Age	WAB-AQ	Apraxia	Dysarthria
Adler	13	Male	52.4	55.8	Yes	Yes
	16	Male	63.5	57.2	Yes	Yes
Elman	09	Female	58.8	57.8	Yes	No
Fridriksson	12	Female	47.9	57.5	Yes	Yes
Scale	01	Male	78.3	52.5	Yes	No
	10	Male	44.7	63.5	Yes	Yes
	26	Male	58.8	64.8	Yes	No
	36	Male	55.2	66.3	Yes	No
Tap	11	Female	62.7	58.1	Yes	No
	14	Male	44.9	60.2	Yes	No
	16	Male	42.9	56.7	Yes	Yes
	17	Female	65.5	59.5	Yes	No
	19	Female	54.7	59.4	Yes	No
Whiteside	11	Female	31.8	72.8	Yes	No
	15	Female	54.9	72.2	Yes	No
Wright	207	Female	63.9	61.5	Yes	No

Note. Data collected from AphasiaBank. The data in this table is similar to the demographic data reported in Pickard (2025).

Speech Recordings

Speech samples from the participants were downloaded from the AphasiaBank database, a publicly available speech recording archive (MacWhinney et al., 2011). The database includes a diverse collection of recordings from PWA and neurologically healthy adults communicating in a variety of different speech tasks. The speech samples in the AphasiaBank database were contributed by a number of different research groups, such as the Snyder Center for Aphasia Life Enhancement, the Adler Aphasia Center, the University of Central Florida, and the Triangle Aphasia Project. All speech recordings were collected using similar protocols and according to the ethical guidelines published by AphasiaBank (MacWhinney et al., 2011).

Speech Task Types

The speech samples examined in this study were elicited in three different speech task types: personal interview, picture description, and personal narrative. In the personal interview condition, the interview involved posed four open-ended questions to participants such as "How do you think your speech is these days?" and "Do you remember when you had your stroke? Can you tell me about it?" In the picture description condition, subjects were shown an active scene in a park setting. The picture involved unique activities such as a man being trapped in a tree, a girl attempting to retrieve her cat also caught in the tree, and two firefighters arriving to assist with a second ladder. The speakers were then asked to provide a verbal description in story form that has a clear beginning, middle, and end. In the personal narrative task type, subjects were asked the question, "Can you tell me a story about something important that happened to you?"

Acoustic Analysis

Transcripts of the recordings were created in chat format by the researchers who elicited and recorded the original speech recordings (MacWhinney et al., 2011). These transcripts were used to separate the speakers' communication into separate utterances. An utterance was excluded from analysis if it met any of the following criteria: "character speech, a question, unfinished words, fewer than two words, an interruption by the examiner, or was unintelligible, directed towards someone else in the room and not related to the narrative, or abandoned" (Patel et al., 2020, p. 3035). The inclusive utterances were then coded according to where it occurs chronologically in the speech sample and each recording was divided into quadrants according to duration (i.e., beginning to 25%, 25% to 50%, 50% to 75%, 75% to end). A random number generator was utilized to select five inclusive utterances in each time quadrant. Thus, this study was designed to extract pitch and intensity measures from 20 utterances per speaker. Occasionally, a recording did not have five qualifying utterances in each quadrant for analysis, in which case measurements were calculated for all inclusive utterances available.

Pitch Measures

The pitch means, pitch variability, and pitch range of each inclusive utterance was calculated through Praat acoustic analysis software (Boersma & Weenink, 2021). As depicted in Figure 1, pitch values were computed every 10 milliseconds by capturing a pitch track (indicated by the blue line) for each utterance produced by participants. The pitch listing function was utilized to extract pitch values into an Excel spreadsheet for further examination. In adherence to Praat recommendations, pitch range configuration was adjusted to account for the sex of the speaker. Male speakers had a pitch range of 75 Hz to 300 Hz, and female speakers had a pitch range of 100 to 500 Hz (Boersma & Weenink, 2021). All measurements were conducted in a linear frequency scale (Hz).

Intensity Measures

Similar to the process used to extract the pitch data, Praat was also used to calculate the intensity mean, intensity range, and variability for each inclusive utterance in the recordings. As depicted in Figure 1, intensity values were calculated every 10 milliseconds by capturing an intensity track (indicated by the green line). The intensity listing function was used to document the extracted intensity values into an Excel spreadsheet for further analysis.

Reliability

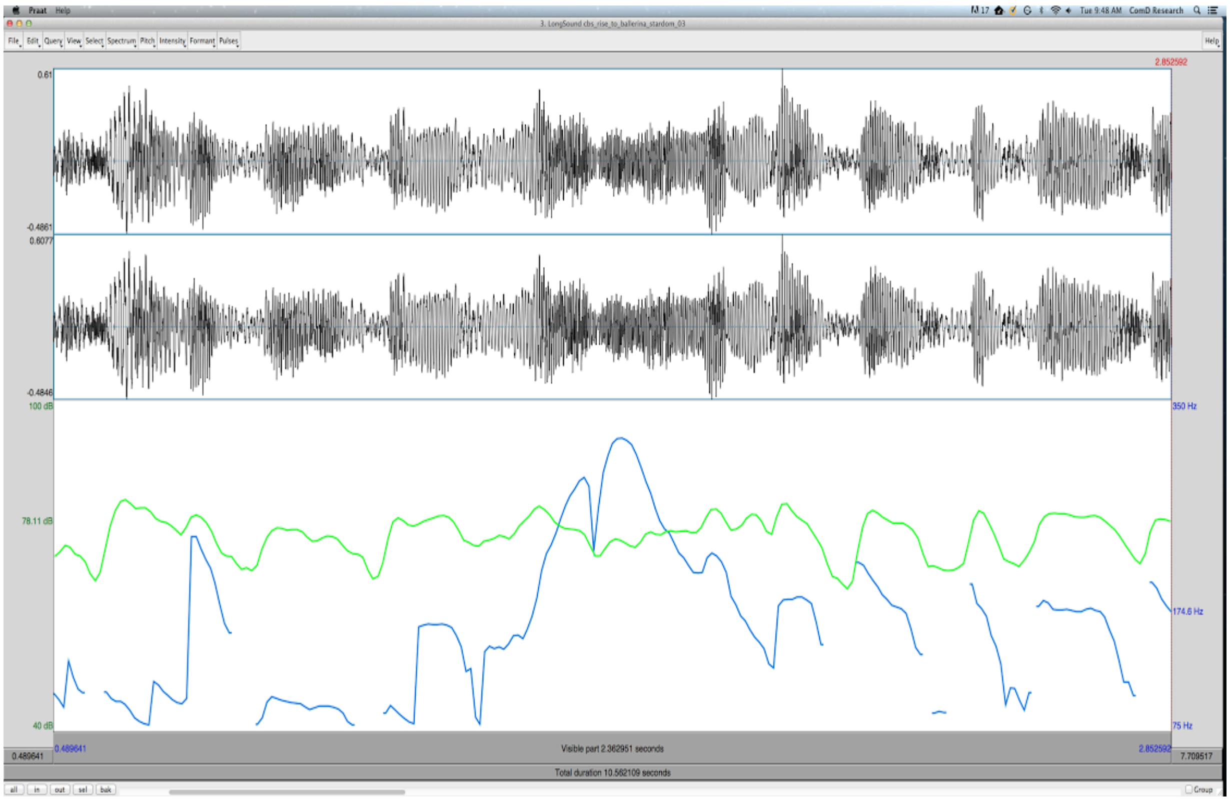
To examine the reliability of the prosodic data, a second researcher remeasured 10% of the extracted pitch and intensity boundaries. The utterances measured a second time were randomly chosen from across the four elicitation tasks and the 32 speaker recordings. The first and second set of boundaries had a Pearson correlation of $r = .91$, $p < .001$.

Statistical Analysis

Descriptive statistics of mean, standard deviation, and range were reported for the dependent pitch and intensity variables. To avoid the impact of outliers in the pitch measures, the lowest and highest 5% of values were trimmed prior to statistical analysis. To determine potential differences in the speakers' pitch and intensity patterns across different task types, a repeated measures using a Two-Way Analysis of Variance (ANOVA) was calculated.

Figure 1

Example of the Extracted Pitch (Blue Line) and Intensity Track (Green Line) Using Praat Acoustic Software



Results

Utterance Duration Measures

No significant differences in utterance duration were found as a function of task type or neurological speaker group. It is important to note that this measure of utterance duration does not take into account differences in the number of syllables or words produced, this was a basic measure of overall time to produce the utterance. A detailed listing of the duration means and standard deviations across task type and speaker group are listed in Table 2 and visually represented in Figure 2.

Table 2

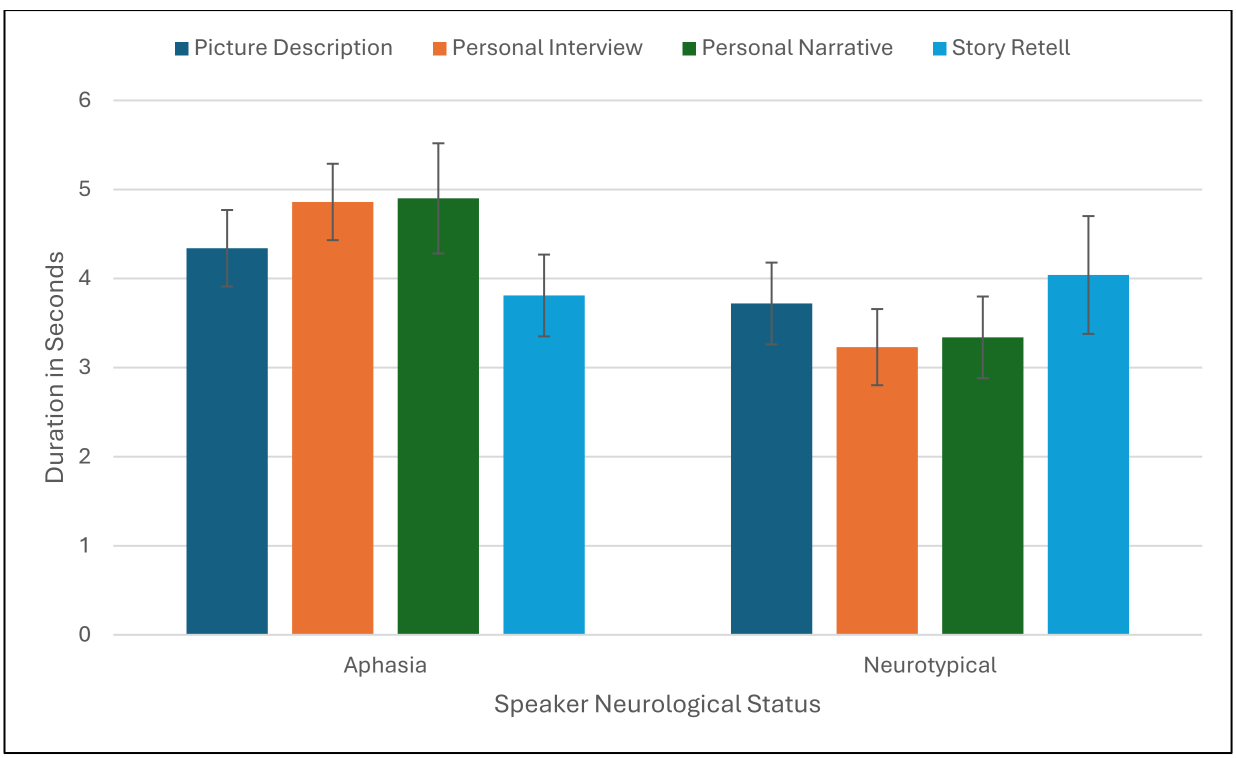
Duration Measures of Neurotypical and Aphasic Participants

Measure	Task[a]	Aphasic Participants		Neurotypical Participants	
		M	*SD*	*M*	*SD*
Utterance duration	PD	4.34	1.86	3.72	1.54
	PI	4.86	1.91	3.23	1.35
	PN	4.90	1.99	3.34	1.32
	SR	3.81	1.81	4.04	3.07

Note. [a] PD = Picture Description; PI = Personal Interview; PN = Personal Narrative; SR = Story Retell.

Figure 2

Utterance Duration Across Speaker Neurologic Status and Speech Task Type



Intensity Measures

For the dependent variable of intensity variability, the ANOVA found a significant main effect across the four speech task types, $F(3,84) = 8.44$, $p < 0.001$, $\eta^2_p = .23$. As shown in Figure 3, when collapsed across both speaker groups the intensity variability was significantly higher in the picture description task ($M = 8.11$ dB), followed by the personal interview ($M = 7.62$ dB), personal narrative ($M = 7.32$ dB), and story retell ($M = 7.19$) condition. There was no significant difference in patterns of intensity variability between the aphasic and neurotypical speaker groups.

Significant differences across speech task were also found for the dependent measure of intensity range, $F(3,84) = 3.39$, $p = 0.02$, $\eta^2_p = .10$. As shown in Figure 4, the intensity variability was significantly higher in the picture description task ($M = 29.94$ dB), than the other three tasks of personal interview ($M = 28.42$ dB), personal narrative ($M = 28.39$ dB), and story retell ($M = 27.35$) condition. The statistical analysis found no additional significant main or interaction effects for the intensity measures as a function of task type or neurological status. Specific mean and standard deviation values can be found in Table 3.

Table 3

Intensity Measures of Neurotypical and Aphasic Participants

Measure	Task[a]	Aphasic Participants		Neurotypical Participants	
		Mean	SD	Mean	SD
Intensity Variance	PD	8.46	1.87	7.76	2.02
	PI	8.47	2.29	6.77	1.21
	PN	7.78	1.84	6.86	1.36
	SR	7.65	2.24	6.72	1.19
Intensity Range	PD	30.36	4.98	29.51	7.07
	PI	30.32	6.34	26.51	4.78
	PN	29.44	5.22	27.34	5.31
	SR	28.10	6.74	27.59	4.76

Note. [a] PD = Picture Description; PI = Personal Interview; PN = Personal Narrative; SR = Story Retell.

Figure 3

Intensity Variability Across Speaker Neurologic Status and Speech Task Type

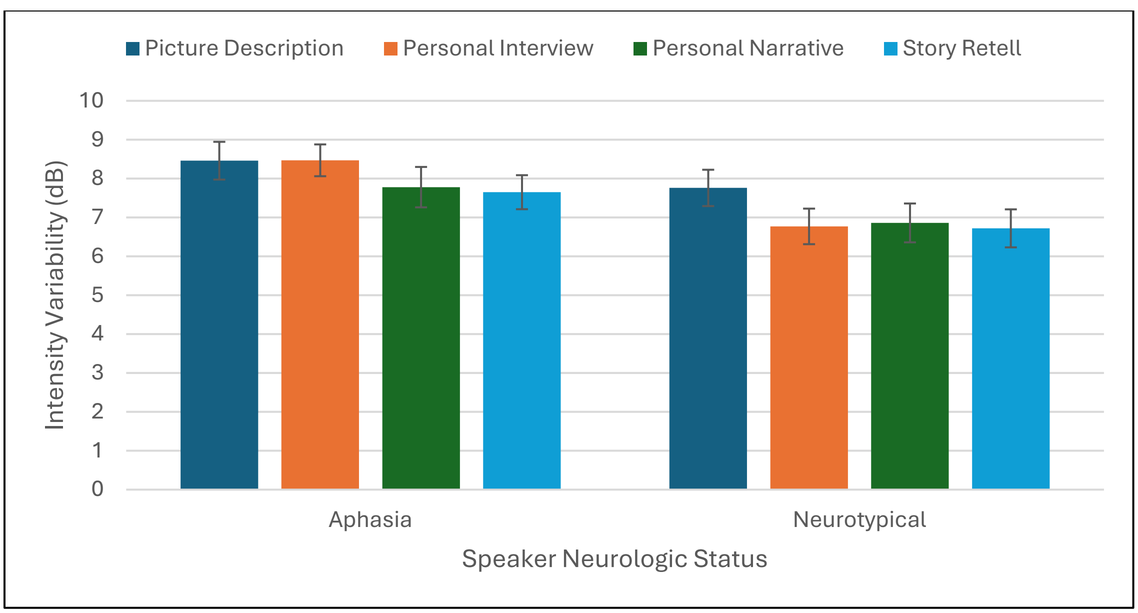
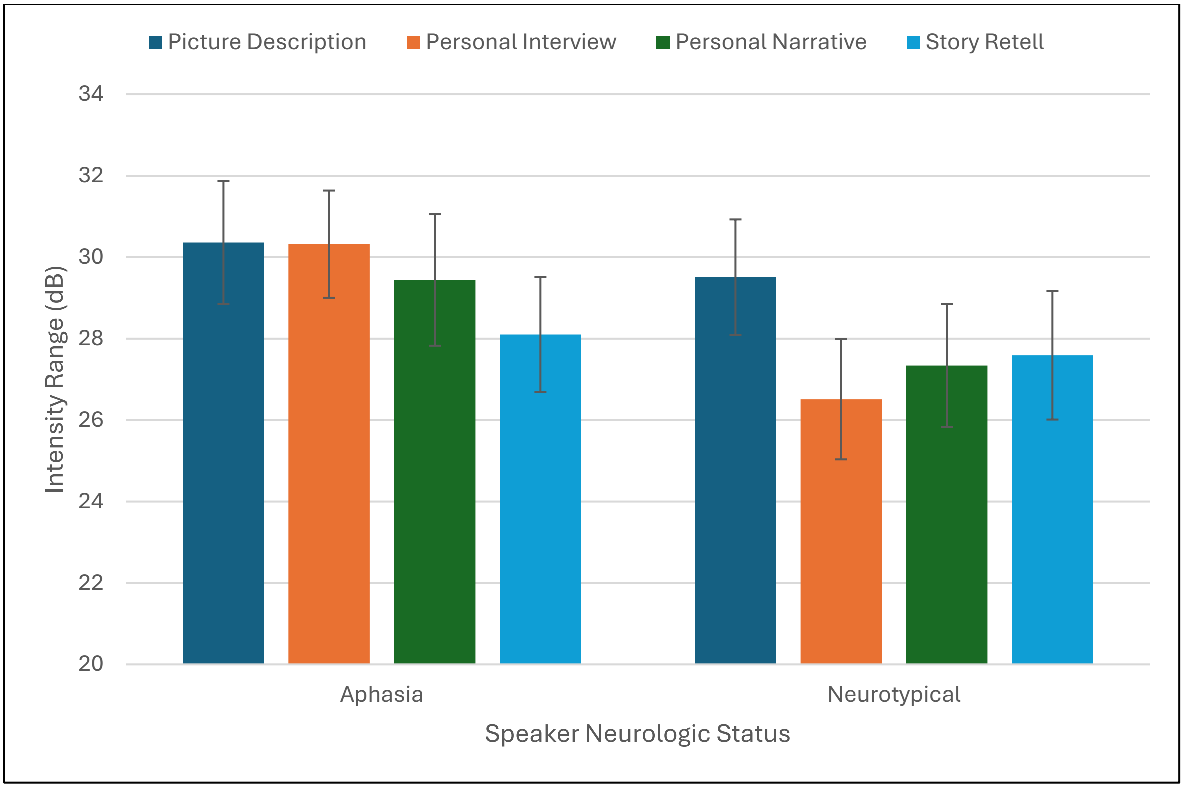


Figure 4

Intensity Range across Speaker Neurologic Status and Speech Task Type



Pitch Measures

The measure of pitch range was found to differ significantly as a function of the speech task type and the neurological status of the speaker, $F(3,84) = 4.31$, $p = 0.007$, $\eta^2_p = .13$. As shown in Figure 5, for aphasic speakers the pitch range was highest for the personal narrative and personal interview speech tasks, and lower for the story retell and picture description tasks. Whereas for the neurotypical speakers, the pitch range was highest in the picture description and story retell tasks, followed by the personal narrative and personal interview. No other significant main or interaction effects for the pitch measures were indicated by the ANOVA. The pitch measure means and standard deviations are detailed in Table 4.

Table 4

Pitch Measures of Neurotypical and Aphasic Participants

Measure	Task[a]	Aphasic Participants		Neurotypical Participants	
		M	*SD*	*M*	*SD*
Pitch Average	PD	172.62	40.61	146.50	45.43
	PI	169.46	46.95	138.15	48.90
	PN	174.38	47.95	145.46	43.71
	SR	167.70	43.91	148.76	46.99
Pitch Variance	PD	29.86	14.55	26.92	9.56
	PI	34.89	15.98	23.55	10.88
	PN	36.02	13.19	28.35	13.17
	SR	30.03	10.49	27.93	12.49
Pitch Range	PD	138.83	74.98	152.47	67.54
	PI	180.08	86.35	126.23	79.04
	PN	189.13	87.39	143.65	76.68
	SR	143.69	69.77	148.11	67.48

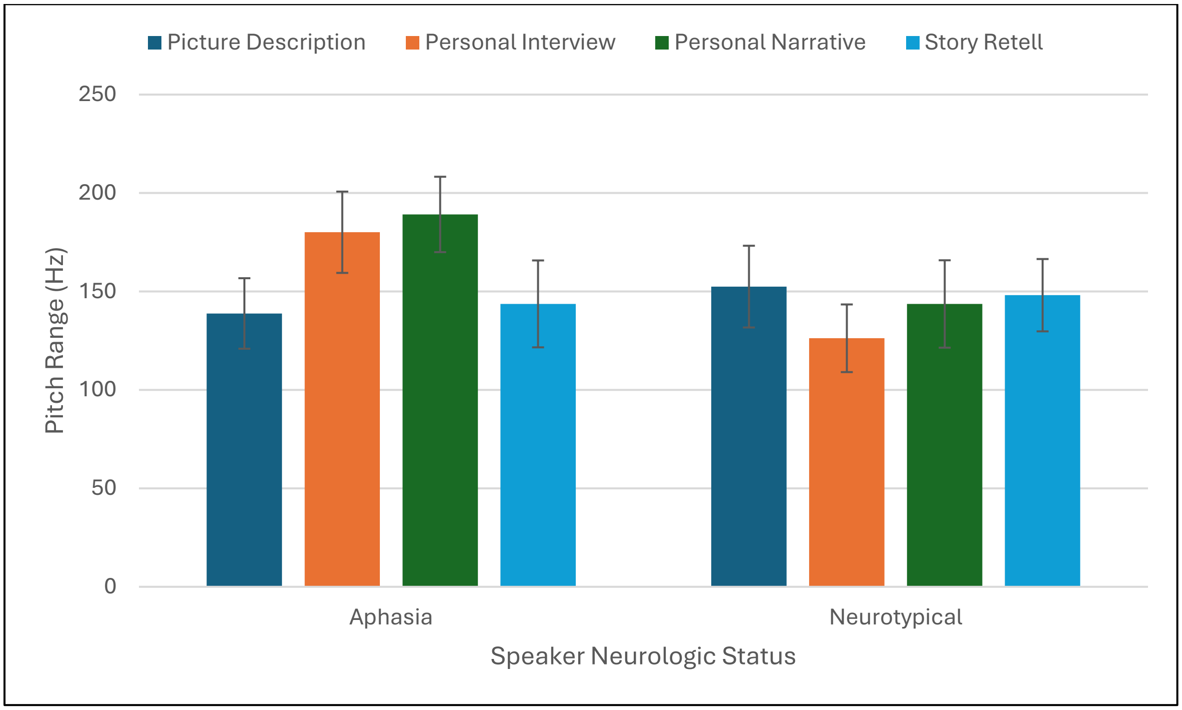
Note. [a] PD = Picture Description; PI = Personal Interview; PN = Personal Narrative; SR = Story Retell.

Discussion

Previous research conducted by Pickard (2025) examined the prosodic patterns of people with moderate non-fluent aphasia, focusing on variations within a single task type (story retell). This study expands upon Pickard's findings by implementing their methodology to examine the pitch and intensity produced by a group of aphasic and neurologically healthy speakers across a variety of task types. The findings of this research study along with its limitations and potential clinical implications are discussed below.

Figure 5

Pitch Range Across Speaker Neurologic Status and Speech Task Type



Intensity Measures

The aim of this study was to evaluate whether individuals with moderate non-fluent aphasia demonstrate atypical patterns of prosodic pitch and intensity across task type compared to age and gender matched individuals without aphasia. The intensity measures showed significant effects of task type, however no significant differences were observed between groups. Intensity variability differed across context, with the picture description task demonstrating the greatest variability, followed by the personal interview, personal narrative and story retell tasks. A similar pattern was observed for intensity range where picture description again elicited the greatest values relative to the other task types. These findings suggest that the communicative demands of a task may influence the degree of intensity variability and range speakers employ.

While it was expected that individuals with Broca's aphasia would demonstrate atypical patterns of both prosodic pitch and intensity compared to the neurologically healthy control subjects, it was found that there were significant differences within the speaker groups across task type in intensity variability. However, there were no significant differences in patterns of intensity variability between aphasic and neurotypical speaker groups. While the intensity range also demonstrated significant differences across speech task, there was no indication that it was a function of neurological status.

As established in the introduction, one of the characteristics of Broca's aphasia is dysprosody. The literature indicates that individuals with Broca's aphasia may exhibit deficits in the production and perception of pitch, although these deficits are not as pronounced as those related to rhythm and timing. Alcock et al. (2000) found that patients with left-hemisphere lesions, including those with Broca's aphasia, were generally not impaired in the production or perception of pitch but showed significant impairments in rhythm production and perception. This suggests that while pitch may be relatively preserved, other aspects of speech prosody, such as rhythm, are more severely affected in Broca's aphasia. While this study found no significant intensity differences as a function of neurological status, dysprosody could still be denoted in impairments in other prosodic elements not evaluated in this study such as pause patterns and timing.

As no significant differences were observed between the aphasic and neurotypical speaker groups for either intensity variability or range, one possible interpretation of these results is that loudness control may be relatively preserved in some individuals with aphasia, particularly when compared to other aspects of language and speech production. However, perhaps the more likely explanation is the limitation of the acoustic measures used to capture intensity differences in this study. Because the speech samples were obtained from the AphasiaBank's existing database (MacWhinney et al., 2011), this study did not account for variations in the recording set-ups for these tasks. As the different samples were not standardized or calibrated, the intensity variability and range are limited to within subjects as there is not a fixed reference.

Pitch Measures

In contrast to intensity, the ANOVA found pitch range to differ significantly both as a function of task type as well as a speaker's neurological status. These findings suggest that the differing patterns between groups may reflect the broader differences in how speakers with aphasia allocate cognitive and linguistic resources during speech production. Because aphasia can affect lexical access, syntactic formulation, and overall language planning, individuals with aphasia may prioritize core linguistic content during more structured discourse tasks. Consequently, prosodic modulation such as pitch variation may be reduced when cognitive demands increase. Conversely, in more familiar conversational contexts, individuals with aphasia may demonstrate relatively greater prosodic flexibility.

These findings also highlight the importance of task selection when evaluating prosodic features in aphasia research. The observed interaction suggests that pitch measures may vary not only by neurological status but also by the communicative and cognitive demands of the elicitation task. Researchers and clinicians should therefore consider how different discourse contexts may influence prosodic performance when assessing individuals with aphasia.

Limitations of the Current Study

There were several limitations with this study that should be acknowledged. The first of such limitations is the standardization of the acoustic recordings. Acoustic intensity can be influenced by recording conditions such as microphone placement and speaker distance. As previously mentioned, these speech samples for the tasks were obtained from the AphasiaBank and had a variety of contributors. This made the calibration or standardization of the recording devices and conditions not possible for this study which limited intensity interpretations. Adjusting these conditions in future could expand the understanding of intensity in PWA by broadening the comparisons between participants that could be evaluated.

This study was also limited by its sample size of 16 PWA and 16 controls, which is relatively small. Increasing the sample size in future studies analyzing dysprosody would allow for more insight into the significant differences that exist between neurotypical individuals and PWA across various prosodic elements. By including more participants, future larger-scale studies would provide the data needed to confirm the validity of these results.

Another limitation of this study is that its scope included a focus on only pitch and intensity in individuals with moderate Broca's aphasia. While other related studies with similar methodology such as Pickard (2025) can provide information regarding other prosodic elements, these also focus on this specific population of individuals with Broca's aphasia. The findings of this study can provide insight into this specific population; however they cannot be applied to other PWA who have different subtypes of severities than those explored in this study. Future consideration for studies would be expanding the participants to include other subtypes of non-fluent aphasia as well as mild and severe severities. This would be beneficial as the results of this study can be further generalized to the treatment of dysprosody in individuals with a variety of non-fluent aphasia.

Conclusions

Despite the limitations that exist in this study, these findings still contribute to the growing body of literature examining prosodic characteristics of aphasia and underscore the need for continued research into the influence of task type on pitch and intensity measures. By conducting research such as this study, it is hoped that clinicians may come to better understand dysprosody in PWA when evaluating prosodic aspects and guiding clinical assessments and interventions for individuals with aphasia. Hopefully this understanding will allow clinicians to better support and appropriately assess and treat PWA as they strive to develop lasting relationships and interact with their environments.

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APPENDIX A

Annotated Bibliography

Alyahya, R. S. W., Halai, A. D., Conroy, P., & Lambon Ralph, M. A. (2020). A unified model of post-stroke language deficits including discourse production and their neural correlates. *Brain: A Journal of Neurology*, *143*(5), 1541–1554. https://doi.org/10.1093/brain/awaa074

Objective: To characterize how different discourse genres (descriptive, narrative, procedural) influence language performance and to identify the core components underlying connected speech, integrating behavioral measures with neuropsychological and neural correlates. *Methods:* This study included 46 individuals with chronic post-stroke aphasia (≥12 months post-onset following a single left-hemisphere stroke) and 20 age- and education-matched neurotypical controls. Aphasia diagnosis and classification were established using the Boston Diagnostic Aphasia Examination (BDAE). Participants produced three connected speech samples: (1) descriptive discourse using the Cookie Theft picture, (2) narrative discourse using an 8-picture "Dinner Party" sequence, and (3) procedural discourse describing how to make a cup of tea. No time limits or verbal prompts were provided. Speech samples were transcribed and analyzed for measures including lexical diversity, informativeness (content words ÷ total tokens), and words per minute (WPM). In addition, participants completed an extensive battery of language and cognitive tests, including naming (e.g., Boston Naming Test), comprehension (e.g., synonym judgment tasks), phonological processing (PALPA subtests), and executive function measures. *Conclusions*: The results demonstrated that connected speech deficits in aphasia are multidimensional and systematically vary across discourse genres, with

narrative discourse eliciting greater lexical diversity and content word production than other conditions. Relative to controls, individuals with aphasia showed reduced verbal output, informativeness, and lexical diversity across all discourse types.

Baqué L. (2017). Lexical stress contrast marking in fluent and non-fluent aphasia in Spanish: The relationship between acoustic cues and compensatory strategies. *Clinical Linguistics & Phonetics*, *31*(7–9), 642–664. https://doi.org/10.1080/02699206.2017.1305449

Objective: To investigate how individuals with fluent (conduction) and non-fluent (Broca's) aphasia produce lexical stress in Spanish. The primary goal was to determine whether aphasic speakers demonstrate impairments in key acoustic cues including duration, pitch (fundamental frequency), and intensity, and to explore whether these individuals rely on compensatory strategies to maintain stress contrasts despite underlying deficits. *Method*: The study included three groups: individuals with conduction aphasia (fluent), individuals with Broca's aphasia (non-fluent), and neurotypical control participants. Participants were asked to produce disyllabic Spanish words with differing stress patterns (oxytones and paroxytones). Their speech was analyzed acoustically, focusing on duration, pitch (F0), and intensity as markers of lexical stress. The data were examined using mixed-effects regression models to compare how each group produced stress contrasts and to identify differences in cue usage across groups. *Conclusions:* The findings indicated that both fluent and non-fluent aphasic speakers exhibit disruptions in lexical stress production, though the nature of these disruptions differs by group. Individuals with non-fluent (Broca's) aphasia showed broader impairments across multiple acoustic cues but appeared to compensate by increasing reliance on intensity. In contrast, individuals with fluent (conduction) aphasia demonstrated more subtle phonetic deficits. Overall, the study concluded that lexical stress is not fully preserved in aphasia and that speakers may adapt by employing compensatory strategies, highlighting the complex interaction between impairment and adaptation in prosodic speech production.

Chen, Y., Kimelman, M. D., & Micco, K. (2009). Investigation of habitual pitch during free play activities for preschool-aged children. *International Journal of Pediatric Otorhinolaryngology*, *73*(1), 73–80. https://doi.org/10.1016/j.ijporl.2008.09.016

Objective: To compare the habitual pitch measured in two different speech activities (free play activity and traditionally used structured speech activity) for normally developing preschool-aged children to explore to what extent preschoolers vary their vocal pitch among different speech environments. *Methods:* Habitual pitch measurements were conducted for 10 normally developing children (two boys, eight girls) between the ages of 31 months and 71 months during two different activities: (1) free play; and (2) structured speech. Speech samples were recorded using a throat microphone connected with a wireless transmitter in both activities. The habitual pitch (in Hz) was measured for all collected speech samples by using voice analysis software (Real-Time Pitch). *Conclusions:* Significantly higher habitual pitch is found during free play in contrast to structured speech activities. In addition, there is no significant difference of habitual pitch elicited across a variety of structured speech activities. *Relevance to Current Study:* Utilized to establish pitch variance across task type in neurotypical individuals and how findings in children (which can reasonably be applied to adults) indicate differences across unstructured conversation found in free play vs structured conversations/activities

Cole, J., Mo, Y., & Baek, S. (2010). The role of syntactic structure in guiding prosody perception with ordinary listeners and everyday speech. *Language and Cognitive Processes*, 25(7–9), 1141–1177. https://doi.org/10.1080/01690960903525507

Objective: This study evaluates the perception of prosody in conversational speech. Specifically, it focuses on syntactic structures and acoustic cues to manipulate the prosody of each sentence. Prosodic structures are characterized by changes in segmental properties and suprasegmental properties (including pitch, loudness, and duration).

Method: Ninety-seven participants were asked to transcribe the location of boundaries (referred to as "chunks") between 72 excerpts from the Buckeye Corpus of spontaneous, conversation-style speech. The transcriptions are based solely on auditory impressions.

Conclusions: The study concluded that untrained listeners are consistent and systematic in perceiving prosodic boundaries in spontaneous conversational speech, and the boundaries are correlated to syntactic markings. Relevance to current study: It is important to understand that prosody changes, thus pitch changes, can be perceived by the untrained listener, and can also be perceived in an aphasic population as well.

Gavarró, A., & Salmons, I. (2013). The discrimination of intonational contours in Broca's aphasia. *Clinical Linguistics & Phonetics*, *27*(8), 632–646. https://doi.org/10.3109/02699206.2013.800908

Objective: To investigate whether individuals with Broca's (agrammatic) aphasia are able to perceive and discriminate intonational contours associated with different syntactic structures and to determine whether prosodic comprehension deficits in agrammatic aphasia reflect a general impairment in prosodic processing or whether individuals retain the ability to perceive intonation contrasts independently of broader language deficits.

Methods: This study included 10 individuals with Broca's aphasia and 10 neurologically typical control participants, matched for age and language background. Participants completed a prosodic discrimination task in which they were presented with pairs of spoken sentences that differed only in their intonational contour, corresponding to different syntactic constructions. The stimuli were controlled such that segmental (lexical) information remained constant, isolating prosody as the primary cue. Participants were required to judge whether sentence pairs were identical or different, and performance was measured using accuracy scores. The experimental design included multiple stimulus pairs across conditions, allowing for statistical comparison between groups. Analyses focused on whether participants could reliably discriminate intonation patterns associated with grammatical contrasts, independent of lexical-semantic processing. *Conclusions:* Findings demonstrated that individuals with Broca's aphasia performed comparably to neurologically typical controls in discriminating intonational contours, indicating preserved prosodic perception abilities despite significant impairments in other language domains. These findings suggest that prosodic processing may remain relatively intact in agrammatic aphasia. Importantly, the study supports the interpretation that previously observed comprehension deficits in aphasia are not due to a fundamental inability to perceive prosody, but rather to difficulties in integrating prosodic information with syntactic and semantic processing during real-time language comprehension. Overall, the findings contribute to a growing body of evidence that prosody and syntax may be partially dissociable systems, with prosodic perception serving as a relative strength in individuals with agrammatic aphasia.

Haley, K. L., Jacks, A., Jarrett, J., Ray, T., Cunningham, K. T., Gorno-Tempini, M. L., & Henry, M. L. (2021). Speech metrics and samples that differentiate between non-fluent/agrammatic and logopenic variants of primary progressive aphasia. *Journal of Speech, Language, and Hearing Research*, *64*(3), 754–775. https://doi.org/10.1044/2020_JSLHR-20-00445

Objective: To identify speech metrics and discourse sampling methods that effectively differentiate between the non-fluent/agrammatic (nfvPPA) and logopenic (lvPPA) variants of primary progressive aphasia. The primary objective was to determine which acoustic, temporal, and linguistic features of connected speech best distinguish these variants, addressing the clinical challenge of accurately classifying PPA subtypes based on behavioral speech characteristics. *Methods:* The study included individuals diagnosed with primary progressive aphasia, specifically comparing nfvPPA and lvPPA groups, along with a neurologically typical control group. Participants completed multiple speech elicitation tasks, including structured and semi-structured discourse samples (e.g., picture description and narrative tasks). Speech was transcribed and analyzed using a range of quantitative speech metrics, including speech rate, articulation rate, pause frequency and duration, grammatical complexity, and error types. The dataset included dozens of participants across groups (typical PPA studies include sample sizes in the range of ~10–30 per subgroup), and each participant contributed multiple speech samples to ensure reliability. Statistical analyses (including group comparisons and classification modeling) were conducted to determine which speech features most effectively discriminated between nfvPPA and lvPPA. *Conclusions:* Results demonstrated that speech timing and fluency-related measures were among the most robust differentiators between PPA variants. Specifically, individuals with nfvPPA exhibited reduced speech rate, increased pause frequency, and greater articulatory disruption, reflecting underlying motor speech and grammatical impairments. In contrast, individuals with lvPPA showed relatively preserved motor speech but increased word-finding difficulty and lexical retrieval errors.

Hunter, E. J. (2009). A comparison of a child's fundamental frequencies in structured elicited vocalizations versus unstructured natural vocalizations: A case study. *International Journal of Pediatric Otorhinolaryngology*, *73*(4), 561–571. https://doi.org/10.1016/j.ijporl.2008.12.005

Objective: To investigate the difference in a child's fundamental frequency during structured, elicited tasks and long-term unstructured activities. *Methods:* A healthy male child (5 years, 7 months) was evaluated. The child completed four voice tasks used in a previous study of the influence of task type on F 0 values: (1) sustaining the vowel/ a / in isolation; (2) sustaining the vowel/ a / embedded in a word at the end of a phrase; (3) repeating a sentence; and (4) counting from 1 to 10. The child also wore a National Center for Voice and Speech voice dosimeter, a device that collects voice data over the course of an entire day, during all activities for 34 h over 4 days. *Conclusions:* Throughout the structured vocal tasks within the clinical environment, the child's F 0, as measured by both the dosimeter and acoustic analysis of microphone data, was similar for all four tasks, with the counting task the most dissimilar. However, the child's mean fundamental frequency during the unstructured activities was significantly higher (∼376 Hz). Indicates variances in how children may adapt their fundamental frequencies to various environments, conversations, and activities. *Relevance to Current Study:*

Similarly to the Chen et al. study (2009) this study helps to establish that in neurotypical individuals, variance in pitch can be expected based on changes in speech task type.

Kertesz, A. (2006). *Western Aphasia Battery--Revised (WAB-R)* [Database record]. APA PsycTests. https://doi.org/10.1037/t15168-000

Objective: The purpose of this assessment is to characterize expressive language production and comprehension, reading and writing, and other visual spatial skills. The subtests include spontaneous speech, repetition, naming and word finding, auditory verbal comprehension. *Relevance to current study:* This test is used to diagnose and categorize aphasia.

Leaman, M. C., & Edmonds, L. A. (2021). Assessing language in unstructured conversation in people with Aphasia: Methods, psychometric integrity, normative data, and comparison to a structured narrative task. *Journal of Speech, Language, and Hearing Research*, *64*(11), 4344–4365. https://doi.org/10.1044/2021_JSLHR-20-00641

Objective: To evaluate the use of language measures derived from unstructured conversation in individuals with aphasia and compare them to a traditional structured narrative task. The researchers sought to determine the reliability, stability, and validity of these measures, as well as whether conversational speech provides meaningful and clinically relevant information beyond standardized, structured language assessments. *Method*: The study included 20 individuals with aphasia and 20 neurologically typical adults. Each participant completed two language tasks: an unstructured conversational interview and a structured narrative task (storytelling). Researchers analyzed seven linguistic variables, including percent correct information units (CIUs), CIUs per minute, grammaticality, and measures of discourse such as cohesion and coherence. To evaluate consistency, interrater reliability was calculated using two independent raters, and test–retest reliability was assessed by having a subset of participants complete the tasks again. Statistical analyses were conducted to compare performance across groups and between task types. *Conclusions*: The findings indicated that language measures derived from unstructured conversation are reliable, stable, and sensitive to differences between individuals with and without aphasia. Additionally, conversational tasks captured aspects of communication that structured narratives did not, highlighting their unique clinical value.

Leung, J. H., Purdy, S. C., Tippett, L. J., & Leão, S. H. (2016). Affective speech prosody perception and production in stroke patients with left-hemispheric damage and healthy controls. *Brain and Language*, 166, 19–28. https://doi.org/10.1016/j.bandl.2016.12.001 *Objective:* To investigate affective speech prosody perception and production in individuals with left-hemisphere stroke, including those with aphasia. The authors sought to determine whether deficits in emotional prosody are present following left-hemisphere damage and to clarify the extent to which prosodic impairments reflect linguistic versus affective processing deficits. *Methods:* This study included 17 individuals with left-hemisphere stroke (of whom 10 were diagnosed with aphasia) and 14 neurologically healthy control participants matched for age and education. Participants completed both prosody perception and production tasks. In the perception task, individuals identified emotions (e.g., happy, sad, angry) conveyed through prosodic cues in spoken sentences, and performance was quantified using percent accuracy scores. In the production task, participants were instructed to produce sentences with specified emotional intonation, which were subsequently evaluated through listener judgment ratings and acoustic analyses of prosodic features such as pitch (F0), intensity, and duration. Group differences were assessed using inferential statistical analyses to compare performance across perception and production domains. *Conclusions:* The results indicated that individuals with left-hemisphere stroke, including those with aphasia, demonstrated significant impairments in both the perception and production of affective prosody, although the severity and pattern of deficits varied across participants. These findings challenge the traditional right-hemisphere dominance account of emotional prosody and instead support a bilateral neural model, in which the left hemisphere contributes to both affective and linguistic aspects of prosody. The study highlights that prosodic processing deficits in aphasia may arise from interacting disruptions across multiple linguistic and affective systems, rather than from a single localized impairment.

Sheppard, S. M., Love, T., Midgley, K. J., Shapiro, L. P., & Holcomb, P. J. (2019). Using prosody during sentence processing in aphasia: Evidence from temporal neural dynamics. *Neuropsychologia*, *134*, 107197. https://doi.org/10.1016/j.neuropsychologia.2019.107197 *Objective:* This study aimed to investigate how individuals with agrammatic aphasia process prosodic cues during real-time sentence comprehension, with a particular focus on the role of intonational phrase boundaries in resolving syntactic ambiguity and how prosodic processing interacts with syntactic complexity. *Methods:* The study included 10 individuals with agrammatic aphasia (after exclusion of one participant due to excessive EEG artifact rejection) and 19 age-matched neurologically typical controls (originally 20, with one excluded due to noise). All were English speakers and the PWA were at least 6 months post left-hemisphere stroke with confirmed diagnoses of aphasia using the BDAE. Participants listened to 120 experimental sentences and 24o filled sentences.

Prosodic boundaries were acoustically manipulated and quantified. *Conclusion:* Results found neurologically typical controls showed robust CPS effects in both early and late closure conditions, indicating efficient and immediate sensitivity to prosodic boundaries during sentence processing. In contrast, individuals with agrammatic aphasia exhibited delayed CPS responses across both conditions, providing strong evidence for slowed neural processing of prosodic information rather than a complete deficit. Behaviorally, the aphasia group also showed reduced accuracy on acceptability judgments (61.65%) compared to controls (78.9%), indicating impaired offline sentence comprehension.

Vuković, M., Sujić, R., Petrović-Lazić, M., Miller, N., Milutinović, D., Babac, S., & Vuković, I. (2012). Analysis of voice impairment in aphasia after stroke-underlying neuroanatomical substrates. *Brain and Language*, *123*(1), 22–29. https://doi.org/10.1016/j.bandl.2012.06.008

Objective: To examine phonation impairments in individuals with aphasia following stroke and to identify the underlying neuroanatomical substrates associated with these deficits. The primary objective was to determine whether cortical lesions, in addition to traditionally implicated subcortical structures, contribute to abnormalities in phonation, and how these impairments differ across aphasia subtypes. *Methods:* The study included 60 male participants with aphasia, divided into three equal groups of 20 based on aphasia subtype: 20 with Broca's aphasia, 20 with Wernicke's aphasia, and 20 with subcortical aphasia, along with a control group of 20 neurologically healthy males matched for age. Participants were instructed to produce sustained phonation of the vowel /a/, which was analyzed using both acoustic and perceptual measures. Acoustic analysis focused on parameters such as fundamental frequency (F0), jitter, shimmer, and harmonic-to-noise ratio, which reflect stability and quality of vocal fold vibration. Perceptual evaluations of voice quality were also conducted. Statistical analyses compared acoustic and perceptual measures across aphasia subtypes and control participants. *Conclusions:* The results demonstrated that individuals with aphasia exhibited significant impairments in phonation compared to controls, including increased variability in acoustic measures such as jitter and shimmer and reduced stability of vocal output. These impairments varied by aphasia subtype, with Broca's aphasia showing the most pronounced deficits, reflecting greater disruption to motor speech planning and execution.

Walker, J. P., Joseph, L., & Goodman, J. (2009). The production of linguistic prosody in subjects with aphasia. *Clinical Linguistics & Phonetics*, 23(7), 529–549. https://doi.org/10.1080/02699200902946944

Objective: To investigate prosody production in people with aphasia. The primary objective was to determine whether PWA can effectively use prosodic cues to convey linguistic contrasts, such as lexical stress, syntactic structure, and sentence modality, and to evaluate how impairments in prosody impact listener comprehension of intended meaning. *Methods:* The study included individuals with left-hemisphere damage (aphasia) and a neurologically typical control group Three experimental tasks were administered: (1) lexical stress contrast production (e.g., noun vs verb forms), (2) compound noun vs syntactic phrase contrasts, and (3) echo questions vs declarative statements. Speech productions were analyzed acoustically using fundamental frequency (F0), duration, and amplitude (intensity) as primary prosodic measures. In addition, naïve listeners were recruited to perform perceptual identification tasks, in which they judged the intended meaning of each utterance. Performance was quantified through acoustic

comparisons between groups and listener accuracy rates, allowing for both objective and perceptual evaluation of prosodic effectiveness. *Conclusions:* Results demonstrated that PWA aphasia exhibit varied prosodic patterns compared to control participants across all three conditions. Acoustic analyses revealed reduced differentiation in key prosodic cues (F0, duration, intensity), limiting the speakers' ability to signal linguistic contrasts. Perceptually, naïve listeners showed significantly lower accuracy in identifying intended meanings from PWA, indicating that prosodic impairments had functional communicative consequences.

Zipse, L., Gallée, J., & Shattuck-Hufnagel, S. (2025). A targeted review of prosodic production in agrammatic aphasia. *Neuropsychological Rehabilitation*, *35*(4), 863–903. https://doi.org/10.1080/09602011.2024.2362243

Objective: To conduct a targeted literature review of prosodic production in individuals with agrammatic aphasia. The primary objective was to evaluate the extent to which speakers with agrammatic aphasia are able to produce prosody and to determine whether observed deficits reflect impaired prosodic competence versus limitations in motor speech execution. The study further sought to clarify inconsistencies in the literature by examining how methodological differences influence interpretations of prosodic ability in this population. *Methods:* This study used a targeted literature review methodology, synthesizing findings from previously published empirical studies on prosodic production in agrammatic aphasia. The authors systematically examined studies that included individuals with agrammatic (non-fluent) aphasia, focusing on tasks that elicited prosodic features such as fundamental frequency (F0), duration, and intensity. Across the reviewed literature, sample sizes varied substantially, with individual studies typically including small cohorts (often fewer than 20 participants with aphasia) alongside neurologically typical comparison groups. The review analyzed how prosody was measured across studies, including acoustic analyses, perceptual ratings, and task-based elicitation paradigms (e.g., sentence production, contrastive stress tasks). Additionally, the authors evaluated whether studies accounted for motor speech impairments (e.g., apraxia of speech, dysarthria) as potential confounding variables influencing prosodic output.

Conclusions: Review concluded that evidence for prosodic impairment in agrammatic aphasia is mixed and highly dependent on methodological factors, rather than reflecting a uniform deficit. Critically, the findings suggest that individuals with agrammatic aphasia often retain underlying prosodic knowledge, but may demonstrate impaired prosodic realization due to co-occurring motor speech deficits that limit their ability to execute acoustic cues. Studies that controlled for motor speech impairments were more likely to show relatively preserved prosodic structure, whereas those that did not often over-attributed deficits to linguistic impairment. Furthermore, the review highlights that prosody is a multicomponent construct, involving interactions between linguistic, cognitive, and motor systems, and therefore cannot be interpreted in isolation.

APPENDIX B

IRB Approval Protocols

TalkBank

IRB Approval

This page explains the principles involved in securing IRB permission for data sharing. If you already have IRB clearance and are ready to contribute your data to TalkBank (CHILDES, AphasiaBank, SLABank, etc.), you should follow these ***instructions*** on how to actually submit your data.

1. IRB Principles

TalkBank members who are interested in contributing their data need to make sure that they obtain IRB approval for their study, along with informed consent from individual participants. There are no standard forms for IRB applications, since every university or institute creates their own forms, procedures, and templates. For the purposes of contributing to TalkBank, the important thing is to select the appropriate level of access to the data that participants are being asked to grant. To help you determine this, we have created an ***OPTIONS summary*** for the 9 options that are available. We would recommend that you ask participants to permit unrestricted access with pseudonymization of the transcripts (Options 1 and 2). You should include on your form the fact that participants always have the right to request that parts or all of the data in which they participate be removed from TalkBank at any time.

2. Contributions of Archival Data

Often researchers will wish to contribute data collected in projects that have already been completed. In such cases, it may be difficult or impossible to contact participants to obtain a new consent form. However, IRBs are allowed to permit including these data in TalkBank, if certain conditions are met.

1. The original consent forms should not have exclusionary language such as “These data will only be made available to Professor XYZ and her laboratory”. If the consent forms says something like “These data will only be made available to qualified researchers,” then inclusion in TalkBank should be allowed, as long as only qualified researchers are given the necessary password. If the consent form is still more general, then passwords may not be necessary.
2. Data should be anonymized.
3. Additional protection is possible, as described on the ***options summary page***.

4. It is important to emphasize that granting agencies stipulate that data collected with federal funds should be made available to researchers, as long as anonymity is preserved.

3. GDPR Compliance

The General Data Protection Regulation (GDPR) establishes rules for personal data on the web. The EU web site for GDPR issues is https://gdpr-info.eu/. In regards to TalkBank, there are five core GDPR issues

1. Commercial purposes issue: GDPR is designed to apply to data transferred for commercial purposes. TalkBank has no commercial purposes. However, it could still apply if TalkBank were to collect emails and addresses, which it does not do.
2. The scientific data issue: A good summary of these issues can be found in ***this Nature article*** which notes that, consent is given “to certain areas of scientific research when in keeping with recognised ethical standards for scientific research.” Article 89 of the GDPR states that, “Where personal data are processed for scientific or historical research purposes or statistical purposes, Union or Member State law may provide for derogations from the rights referred to in Articles 15, 16, 18 and 21 subject to the conditions and safeguards referred to in paragraph 1 of this Article in so far as such rights are likely to render impossible or seriously impair the achievement of the specific purposes, and such derogations are necessary for the fulfilment of those purposes.” In other words, data-sharing is allowed for research purposes. In addition, Recital 113 allows for transfers of data from a limited number of data subjects for scientific purposes for an increase of knowledge.
3. The informed consent Issue: NIH IRB informed consent guidelines are in accord with the GDPR Consent rules. Given this, if participants give consent for making data available to qualified researchers, then this should be approved. GDPR emphasizes also that this consent must be revocable and that there should be methods for allowing participants to revoke consent.
4. The deidentification issue: If data are deidentified, then they are not personal data and are not covered by GDPR and IRB. Data are not be anonymous or deidentified if they have: name plus surname, credit card, telephone, address, or number plate. First name alone is not identifying. It has to be Name plus Surname. Anonymization must be irreversible. This means that contributors should destroy participant names. This holds in both EU and USA. However, the GDPR catch-22 here is that a link to the data needs to be maintained to allow for data removal. The solution for this is to make the information linking to a person only available to a third party “honest broker”. See below for a discussion of identification based on voice samples.
5. The Code of Conduct issue: Article 40 allows for development of a Code of Conduct to facilitate data transfer to non-EU countries. In the case that an institution prefers to have identifiable media stored on servers in the EU, it is possible to implement CORS (cross origin resource sharing) from a CHAT file at CMU to a media server in the EU. This is done by allowing access from https://*.talkbank.org.

4. Deidentification

In order to deidentify transcripts, it is important to replace any last names with the word "Lastname" with a capital L. Also addresses or local city names should be replaced with "Addressname" with a capital A. Other forms include "Cityname", "Schoolname", "Hospitalname" and so on. These same English words should be used even in other languages. It is not crucial to replace children's first names unless they are very unique.

The EU Amnesia project at https://amnesia.openaire.eu provides software for deidentification of spreadsheet data.

The Canadian CONP Ethics and Governance Committee has a series of ***recommendations for deidentification of neuroimaging data*** .

For audio deidentfication, we can then use the occurrences of the terms Lastname and Address in the transcripts to guide the removal of the names and addresses from the corresponding segment in the audio track. You can follow the suggestions in the section of the CLAN manual on "Audio Anonymization" which are also available ***here*** Once this is done, children and others can only be identified by people who already know them. Because of this, contribution of audio is equivalent in IRB terms to contribution of transcripts.

You can also save yourself a lot of trouble if you avoid using idetifying information when making recordings.

Voiceprints

Researchers often ask about whether they need to request additional IRB approval for contributing audio data. The concern is that audio data may be less confidential than transcript data. However, as long as identifying material is removed from both transcripts and audio, they do not present additional confidentiality issues.

Some reviewers and IRB committees believe that spoken data is identifiable through voice recognition technology. However, this judgment is based on a confusion between closed-set identification and open-set identification. Closed-set identification relies on a pre-existing pool of voiceprints from a given group, such as members of a company or subscribers to a service. Open-set identification does not rely on this pre-existing pool of voiceprints. As noted by Togneri and Pullella (2011), "in open-set identification the unknown individual can come from the general population. However as identification is always carried out against a finite, known pool of individuals it is not possible to identify arbitrary people."

Togneri, R., & Pullella, D. (2011). An overview of speaker identification: Accuracy and robustness issues. IEEE circuits and systems magazine, 11(2), 23-61. ***pdf***

As Yuan and Liberman (2008) discovered, speaker identification in even a closed group of Supreme Court judges in TalkBank's SCOTUS corpus is still very difficult.

Yuan, J., & Liberman, M. (2008). Speaker identification on the SCOTUS corpus. Journal of the Acoustical Society of America, 123(5), 3878. ***pdf***

5. Contributions to CHILDES and PhonBank

Although each University and project will have different requirements, contributors often ask for a generic contribution template form, so here is a ***sample CHILDES/PhonBank consent form*** based roughly on the local format at CMU.

6. Contributions to AphasiaBank/DementiaBank/TBIBank/RHDBank:

Research with subjects with disabilities requires additional access restriction, such as password protection. It may also require more complete IRB documentation. In this regard, researchers working with the AphasiaBank protocol will find these additional IRB-approved materials useful:

- A ***generic informed consent*** form in the CMU format.
- Consent form from ***CMU***
- Consent form from ***Emerson***.
- Consent form for ***Mandarin***.
- Consent forms from Indiana University - 2020
    - ***Consent form for PWA***
    - ***Consent form for Control***
    - ***Verbal script for consent***
- Consent forms from Nazareth College
    - ***Consent form for Control***
    - ***Consent form for RHD participant***
    - ***Consent form for student participant***
- Consent forms from Duke University
    - ***Consent form for RHD participant***
    - ***e-consent form for RHD participant***
    - ***Consent form for volunteer participant***
    - ***e-consent form for volunteer participant***
- Full IRB application from ***University of South Florida***.
- Full IRB application from ***Kansas*** with these related documents:
    - ***Consent form for surrogate***
    - ***Consent form for PWA***
    - ***Assent form for PWA***
    - ***Recruitment poster***
- Four picture-based consent forms for people with aphasia:
    - a very ***simple*** one
    - one from ***USF***
    - one from the ***Adler Center***,
    - form for the ***Famous People Protocol***

Contributions to the other three clinical databanks -- DementiaBank, RHDBank, and TBIBank can follow formats similar those given above for AphasiaBank. The issues involved are generally similar.

7. Contributions to FluencyBank

To protect subject confidentiality, all research contributions to FluencyBank are restricted and require password to access. We suggest that new projects use a ***graduated consent form*** developed at the University of Maryland, that allows participants to specify use of video, audio-only, or transcript-only in contributed data.

When communicating with your IRB, you may find the suggestions in this ***briefing sheet*** helpful.

For projects underway, or recently completed, or longitudinal projects in which PIs would like to have an ongoing relationship before making a contribution request of subjects, we have a ***sample post-hoc consent form*** from the University of Maryland.

For completed projects that have used video without permission to share the video, we will work with you to extract the audio tracks from your video files. (Please see Contributing audio, above, for reasons why this may not require additional IRB consideration). Please contact Brian MacWhinney or Nan Bernstein Ratner to determine how best to handle your data.

8. Contributions to HomeBank

Please consult the ***HomeBank guidelines.***

Adler Aphasia Center
Where people touched by Aphasia can comfortably communicate

RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM
AphasiaBank

PURPOSE

We want to collect data for the study of language and communication in people with aphasia.

TASKS

You will be asked to:

- Describe pictures
- Discuss events in your life
- Tell a story
- Complete aphasia tests

RECORDING

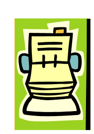
You will be:

- Audio taped
- Videotaped

Your responses will be written out.

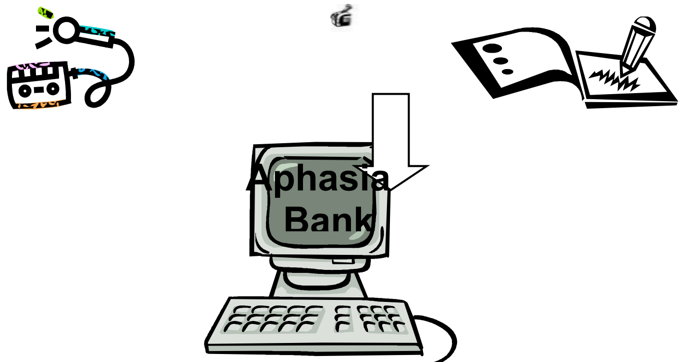
Your name and address will not be recorded.



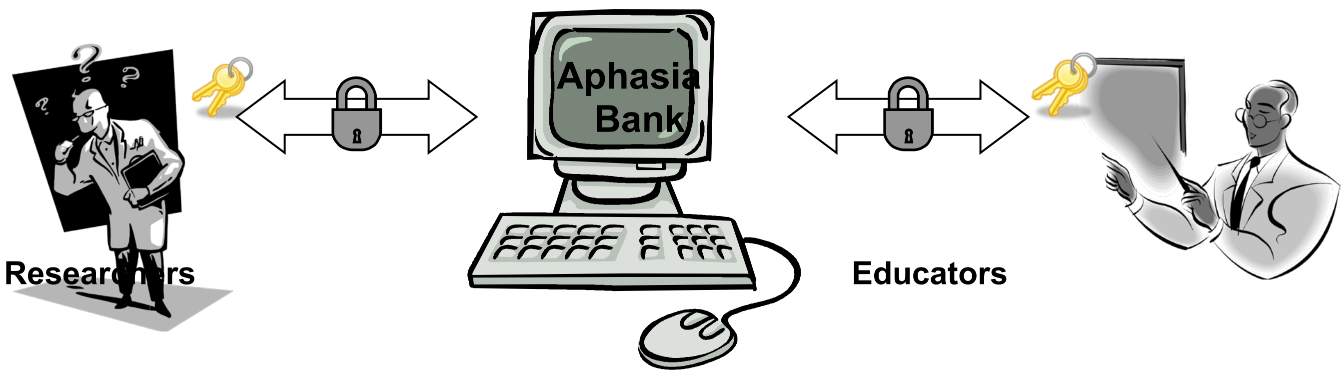


USE

The data from the study will go on an internet database called AphasiaBank.



Researchers and educators with a password will have access the data.



Researchers or educators may use the videos in classes or presentations about aphasia.

There are NO **known** risks or discomforts associated with this study.

COMPENSATION

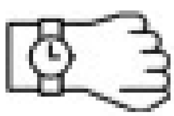
There is no monetary compensation for participating.

BENEFITS

You will help us improve our understanding of aphasia.

We can give you your test results for your files.

It will take 2 to 3 hours.



If you get tired, we can stop and finish another day.

RIGHTS

Your participation is voluntary.

??

??

Yes? ☑ No? ☒

You can stop at any time.

Questions about the study:

Contact
Gretchen Szabo
at
201-368-8585
or
gszabo@adleraphasiacenter.org

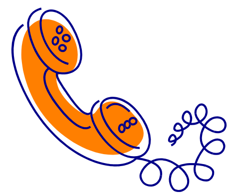
Questions about your rights:

Contact

IRB Chair

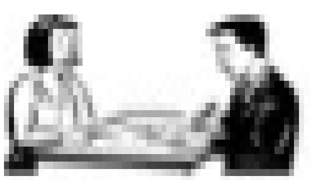
at

201-368-8585



CONSENT TO PARTICIPATE

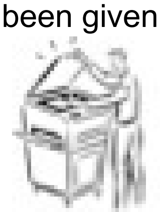
The information on the previous pages has been explained to me



☐ YES  ☐ NO 

____

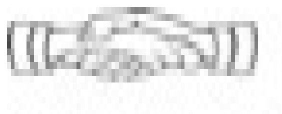
I have been given a copy of this form.



☐ YES  ☐ NO 

____

I agree to participate in the research project.

 ☐ YES  ☐ NO 

______________________________ ___________________
PARTICIPANT SIGNATURE DATE

__________________________________ ____________________
WITNESS SIGNATURE DATE