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Prosodic Pitch and Intensity Patterns in People With  
Moderate Broca's Aphasia

Juliana Pickard

A thesis submitted to the faculty of  
Brigham Young University  
in partial fulfillment of the requirements for the degree of  
Master of Science

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## ABSTRACT

### Prosodic Pitch and Intensity Patterns in People With Moderate Broca's Aphasia

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Master of Science

People with aphasia (PWA) experience deficits in utilizing prosody, which drastically impacts their communicative effectiveness. The lack of prosody in people with aphasia may alter their ability to nurture meaningful relationships, advance educational and work opportunities, and participate in community activities. This study acoustically evaluates the prosodic characteristics of speech produced by individuals with non-fluent aphasia to better understand how to accurately assess and more effectively treat communication difficulties in PWA. Recorded speech samples derived from a Cinderella story retell from 16 individuals with moderate Broca's aphasia and 16 age-matched controls were acoustically analyzed in this study. The recordings were downloaded from AphasiaBank, a database collected from a wide variety of speech tasks produced by individuals with varying types and severity of aphasia, as well as control subjects. Differences as a function of the participants' aphasia status and the chronological location in the speech sample were examined using an Analysis of Variance (ANOVA). The associations between the speakers' Aphasia Quotient (AQ), mean length of utterance, and the extracted pitch and intensity measures were evaluated through Pearson correlations. No significant main effects or interactions were identified for any pitch or intensity measures across speech sample locations or participant aphasia status. However, significant correlations between pitch and intensity measures were noted. Overall, a deeper understanding of prosody in this population can aid clinicians in developing more effective assessment tools and treatment approaches. These advancements have the potential to enhance communicative effectiveness, enabling individuals with Broca's aphasia to build meaningful relationships, pursue educational and career opportunities, and actively engage in their communities.

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

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## DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, entitled *Prosodic Pitch and Intensity Patterns in People With Moderate Broca's Aphasia*, is a component of a larger study exploring the prosodic patterns of speech in people 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, the Institutional Review Board (IRB) approved protocols in Appendix B, and a consent form used in the collection of the data used in this study in Appendix C.

## Introduction

Speech language pathologists (SLPs) commonly assess, diagnose, and treat individuals who have difficulty communicating with others due to neurological injury or disease. About one third of people who experience a cerebral vascular accident, or stroke, acquire aphasia, an “acquired language disorder where patients experience impairments of various aspects of their language system (i.e., phonological, morphological semantic, syntactic, and/or pragmatic)” (Sheppard & Sebastian, 2020, p. 1). People with aphasia (PWA) also experience deficits in utilizing prosody, which drastically impacts their communicative effectiveness. Although effective communication can be attributed to *what* a person says, another crucial aspect is *how* a person says it (through prosody). The altered patterns of prosody in people with aphasia may impact their ability to nurture meaningful relationships, advance educational and work opportunities, and participate in community activities. This study acoustically evaluates the prosodic characteristics of speech produced by individuals with non-fluent aphasia to better understand how to accurately assess and more effectively treat communication difficulties in PWA.

### Characteristics of Aphasia

The nature of language impairment in PWA is a consequence of the location and severity of an individual’s brain damage. A specific type of aphasia diagnosis is also determined by the nature of a speaker’s speech fluency, auditory comprehension, reading and writing, and their ability to repeat words or phrases (Johnson & Jacobson, 2016). Damage that occurs in the parietal or posterior regions of the temporal lobe typically results in *fluent* subtypes of aphasia. Fluent subtypes of aphasia (i.e., Wernicke’s, transcortical sensory, conduction, anomic) often involve relatively fluent verbal production, intact prosody, and varying degrees of impaired

auditory comprehension and repetition. If an acquired brain injury or disease process damages tissue in the frontal or anterior portion of the temporal lobe, the resulting language impairment may result in a *non-fluent* type of aphasia (i.e., global, transcortical motor, Broca's). People with non-fluent subtypes of aphasia have difficulty producing extended segments of connected speech in a fluent manner (Le & Lui, 2023).

The most common form of non-fluent aphasia is Broca's aphasia, named after the French physician who first described the area of the brain in the antero-posterior region of the temporal lobe vital to speech production (Davis, 2007). Broca's aphasia is characterized by deficits in expressive language with relatively intact auditory comprehension. Expressive language in Broca's aphasia is distinguished by halting, effortful speech with a reduced phrase length (Sheppard & Sebastian, 2020). People with Broca's aphasia often have difficulty articulating individual speech sounds and "omit or add phonetic features that do not belong in the proper articulation of a given phoneme" (Damásio, 1992, p. 533). People with Broca's aphasia may struggle to embed and formulate correct syntax within their utterances (Hallowell, 2019). In addition, one of the primary markers of Broca's aphasia is dysprosody or difficulty in comprehending and producing the suprasegmental and emotional features of language (Samuel et al., 1998).

Broca's aphasia is regularly accompanied by apraxia of speech (AOS), a speech disorder that also results from lesions to the left hemisphere of the brain (Ziegler et al., 2022). Apraxia is defined as a "neurologic speech disorder that reflects an impaired capacity to plan or program sensorimotor commands necessary for directing movements that result in phonetically and prosodically normal speech" (Duffy, 2013, p. 4). Apraxia is characterized by sound distortions, sound substitutions, slow speech rate, and abnormal prosody (Bislick et al., 2017).

## Prosody

Prosody is a broad term that covers a wide range of speech characteristics, communicated through changes in a speaker's tempo, pitch, intensity, and vocal quality (Shriberg & Kent, 2013). Linguistically, prosody is used to mark the stress of a syllable and/or word (Ladefoged, 2006). It is also used to indicate to the listener different types of sentences (Geffen et al., 2022). Previous research has found that untrained listeners are consistent in perceiving prosodic boundaries that correlate to syntactic markers in spontaneous conversational speech (Cole et al., 2010). A study by Fox Tree and Meijer (2000) also found that listeners could interpret ambiguous sentences through the prosodic elements of the speech sample.

Speech prosody may also influence a listener's perception of a speaker's personality, such as charismatic, credible, or cooperative. In a study by Rosenberg and Hirschberg (2005), listeners were asked to categorize a series of speech samples into varying emotional states (i.e., charismatic, angry, spontaneous, passionate, and desperate). The speech samples were acoustically analyzed in terms of pitch, intensity, speaking rate, and duration. The study found that the speech samples categorized as charismatic also featured higher maximum pitch, higher standard deviation of pitch, and higher mean intensity. These findings potentially indicate a link between speech prosody and positive listener perceptions.

A study by Niebuhr et al. (2017) evaluated the prosody of speech samples from entrepreneurs with varying levels of perceived charisma in the workplace. Steve Jobs, known for his charismatic and persuasive speech, exhibited a higher average pitch level, larger pitch range, and greater rhythmic variability than other subjects in the study. In contrast, the authors found the speech of Mark Zuckerberg was found to have a lower pitch mean and pitch range. Zuckerberg has been reported by some as having dull presentation skills, which at times has

negatively impacted the perception of Facebook. Interestingly, the study did not examine the speech patterns of female entrepreneurs, which could lead to different prosodic indicators of charisma.

A study by Nissen et al. (2020) found that male television broadcasters tend to speak with greater mean pitch, greater pitch variability, and a larger pitch range than the general male population. In contrast, female television broadcasters tended to speak with a lower mean pitch, compared to pitch patterns found in the general female population. Nissen et al. (2020) hypothesized that the lower mean pitch in female broadcasters may occur from hiring bias and the effects of prosody in listener's perceptions of personality attributes, including credibility. These conclusions are supported by a study which examined the attitudes and speech patterns of a group of radio newscasters conducted by Gasser et al. (2019). Ten newscasters were asked to identify personality traits that were the most important to convey to their listeners. They were asked, "When delivering the news on air, how important is it to you to sound ...," after which they were asked to rank the following eight adjectives related to character and emotional state: (a) trustworthy, (b) charismatic, (c) objective, (d) persuasive, (e) authoritative, (f) enthusiastic, (g) likable, and (h) engaging. The newscasters most frequently selected trustworthiness and engagement. Gasser et al. (2019) also found that female speakers displayed a significantly lower minimum fundamental frequency and a larger standard deviation of pitch when reporting the news compared to their everyday speech. In contrast to the findings of Nissen et al. (2020), the male broadcasters were also found to exhibit lower minimum fundamental frequency in their broadcast speech (Gasser et al., 2019). Although the association is not causal, this study's findings provide some support that both male and female broadcasters may attempt to convey trustworthiness and engagement by behaviorally lowering the pitch of their voice during

broadcasts. Similarly, politicians with greater average intensity, greater pitch range, faster speech rate, and increased frequency of pauses are perceived by listeners to have the highest degree of credibility (Rodero et al., 2014). Additional research supports the theory that individuals adjust their speech prosody to increase the perception of positive personal characteristics, including politicians (Bligh et al., 2005; Gregory & Gallagher, 2002), sales representatives (Bharadwaj & Shipley, 2020), world leaders (Burriss, 2019), and business professionals (Ho, 2021; Leskin, 2019).

Speech prosody is used to communicate emotional meaning and influence social interactions, thereby fostering cooperation among individuals. In a study by Meneses and Díaz (2017), 48 undergraduate students were tasked with determining the emotional tone of 60 variations of the phrase, “Let’s play.” Because phonemic or facial cues were masked, participants relied solely on the prosodic elements of the phrase. The emotional variations of the phrases included joy, anger, and neutrality. Participants also conveyed the likelihood of cooperating or defecting from a group based on the emotional meaning behind each speech sample. The speech samples perceived with the emotional undertone of “joy” possessed a high likelihood to result in cooperation, samples perceived with the emotional undertone of “neutral” possessed a moderate likelihood to result in cooperation, and samples perceived with the emotional undertone of “anger” possessed a reduced likelihood to result in cooperation. Overall, the results indicate a connection between varying probabilities of cooperation and speech prosody.

### **Dysprosody in People with Aphasia**

The amount of research on prosodic production (including pitch, intensity, and timing) in non-fluent (Broca’s aphasia) participants is somewhat limited.

### ***Timing***

Marotta et al. (2008) found that individuals with non-fluent aphasia typically demonstrate atypical prosodic timing due to the production of lengthy pauses within utterances, as well as prolonged syllables within words. The mean length of utterance duration nearly doubles for people with aphasia compared to their control counterparts. When comparing pausing between people with non-fluent and fluent aphasia, Thomas (2021) found people with non-fluent aphasia produce higher mean durations in between- and within-utterance pauses.

There is also some research that examines a larger group of aphasia, which includes Broca's aphasia, called left hemisphere dysfunction (LHD). People with LHD also have difficulty with altering pause duration to differentiate noun compounds from noun phrases (e.g. "green house" vs. "greenhouse"; Emmorey, 1987). Baum et al. (1997) found that people with LHD produce shorter durations in pre-boundary syllables.

### ***Pitch and Intensity***

People with aphasia demonstrate dysprosody, specifically in pitch and intensity, compared to individuals with healthy neurological status in many linguistic contexts. LHD participants produce a three-word color sequence with abnormal fundamental frequency (F0) patterns, specifically an absence of a fall in F0 or increase in F0 variation in pre-boundary words (Baum et al., 1997). Furthermore, PWA also produce abnormal prosody at the word level. In a study conducted by Walker et al. (2009), 10 people with LHD were given 10 pairs of two syllable words: a noun with stress on the first syllable or a verb with stress on the second syllable. Participants with LHD produced abnormal acoustic features compared to the control group. Specifically, LHD participants produced a lower F0 compared to the neurologically

healthy group. Additionally, the participants with LHD produced a smaller range in the intensity of the stressed and unstressed syllables.

Dysprosody is also apparent in emotional and affective contexts. Leung et al. (2016) illustrated the difficulty that people with LHD have when producing and perceiving affective prosody. Subjects were asked to mimic speech tasks, while conveying target emotions. Speech tasks included repetitive monosyllabic, spontaneous monosyllabic, and spontaneous word or sentence tasks. Their responses were analyzed for fundamental frequency, frequency range, minimum frequency, maximum frequency, and standard deviation for frequency. Patients with LHD produced significantly different prosodic productions in emotional expressions of words and monosyllables, including atypical pitch ranges. Additionally, the authors found a positive correlation in the severity of the aphasia and the presence of dysprosody.

### **Prosodic Treatments and Assessments**

As outlined by Hawthorne and Fischer (2020), common protocols and methodologies to treat prosody include Melodic Intonation Therapy (MIT), Dynamic Temporal and Tactile Cueing (DTTC), Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT), and Lee Silverman Voice Treatment (LSVT). These protocols aim to treat prosody directly. In contrast, common assessment batteries used to diagnose aphasia evaluate prosody in a superficial manner. This includes the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006), the Boston Naming Test (BNT; Goodglass et al., 2001), the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001), and the Communicative Effectiveness Index (CETI; Lomas et al., 1989) (Cherney et al., 2018). As outlined by Hawthorne and Fischer (2020), it may be beneficial to utilize direct assessments of prosody. These assessments include the Profiling Elements in Speech-Communication (PEPS-C; Gibbon & Smyth, 2013), the Prosody-Voice Screening Profile

(PVSP; Shriberg et al., 1992), and the Linguisystem's Prosody Treatment Program Screener (Rothstein, 2013).

### **Purpose of This Study**

Not only do SLPs assess, diagnose, and treat the production of individual speech sounds, words, and sentences, they also emphasize the incorporation of prosodic elements in speech. This approach focuses not only on what the individual says, but also on how they say it. An important part of communication is the prosodic features of language that are used to modify, highlight, or convey specific meanings of spoken messages. This is a critical component for building and maintaining meaningful relationships because the essence of a person is fundamentally linked to their expression of feelings and ideas. Hence, SLPs help people with aphasia to express their emotions through integrating prosody. Some people with aphasia may exhibit atypical patterns of pitch or intensity in their speech, which may decrease the effectiveness of their communication. Lack of prosodic elements in speech might reduce their ability to create deep connections in personal life, school, or work and to appear charismatic and credible. Thus, the purpose of this study is to explore the following research questions:

1. Do individuals with Broca's aphasia exhibit atypical patterns of prosodic pitch and intensity compared to control subjects? It is expected that individuals with Broca's aphasia will exhibit atypical patterns of prosodic pitch and intensity compared to control subjects.
2. Do pitch and intensity measures change during the time of the task (i.e., beginning, middle, and end)? It is expected that the pitch and intensity will not change during the time of the task.

3. Does the Aphasia Quotient (AQ) score of aphasic subjects correlate to the pitch and intensity measures? It is expected that individuals with high AQ scores will have atypical pitch and intensity measures.

### **Method**

This study is part of a larger collaborative project examining the prosodic patterns of speech in people with Broca's aphasia. Thus, the speech recordings and transcripts used in this study will be similar to research conducted by Newcombe (2024), Low (2025), and Smith (2025), with a unique contribution focused on the pitch and intensity patterns of participants' speech communication.

#### **Speech Recordings**

Recorded speech samples from 16 individuals with moderate Broca's aphasia and AOS and 16 age-matched controls were acoustically analyzed in this study. The recordings were downloaded from AphasiaBank (MacWhinney et al., 2011), a database collected from a wide variety of speech tasks produced by individuals with varying types and severity of aphasia, as well as control subjects. The specific recordings used in this study were provided by several research groups, including Maura Silverman of Triangle Aphasia Project (TAP), Janet Whiteside of the University of Central Florida, Julius Fridiksson of the Aphasia Lab of the University of South Carolina, Denise McCall of the Snyder Center for Aphasia Life Enhancement (SCALE), and Gretchen Szabo of the Adler Aphasia Center. Each group elicited and collected the speech samples according to a standard protocol outlined by AphasiaBank. Demographic information regarding the 16 aphasic speakers is reported in Table 1.

The AphasiaBank protocol is composed of four separate speech tasks, including personal narrative, picture description, story retell, and procedural discourse. To elicit each speech task,

the interviewers utilized a specific script. For this study, speech samples from only the story retell task were analyzed. For the narrative retell task, speakers first read a short picture book story of *Cinderella* to familiarize themselves with the plot, characters, and setting. Then, the book was removed, and the speakers were asked to recount the story with instructions to “tell as much of the story as you can remember” (MacWhinney et al., 2011). The number of utterances found in the speech sample of the aphasic group is found in Table 1.

### **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.

**Table 1***Demographic Information for Participants With Moderate Broca's Aphasia*

Study	Subject	Gender	Age	WAB-AQ	Number of Utterances in Sample	Apraxia?	Dysarthria?
Adler	13a	Male	78.3	52.5	105	Yes	Yes
	16a	Male	44.7	63.5	15	Yes	Yes
Elman	09a	Female	49.6	60.9	14	Yes	No
Fridriksson	12a	Female	58.8	64.8	45	Yes	Yes
Scale	01a	Male	57.4	71.1	38	Yes	No
	10a	Male	55.2	66.3	36	Yes	Yes
	26a	Male	62.7	58.1	18	Yes	No
	36a	Male	44.9	60.2	59	Yes	No
Tap	11a	Female	42.9	56.7	14	Yes	No
	14a	Male	65.5	59.5	8	Yes	No
	16a	Male	54.7	59.4	20	Yes	Yes
	17a	Female	63.5	57.2	16	Yes	No
	19a	Female	52.4	55.8	59	Yes	No
Whiteside	11a	Female	31.8	72.8	13	Yes	No
	15a	Female	70.5	54.3	80	Yes	No
Wright	207a	Female	54.9	72.2	81	Yes	No

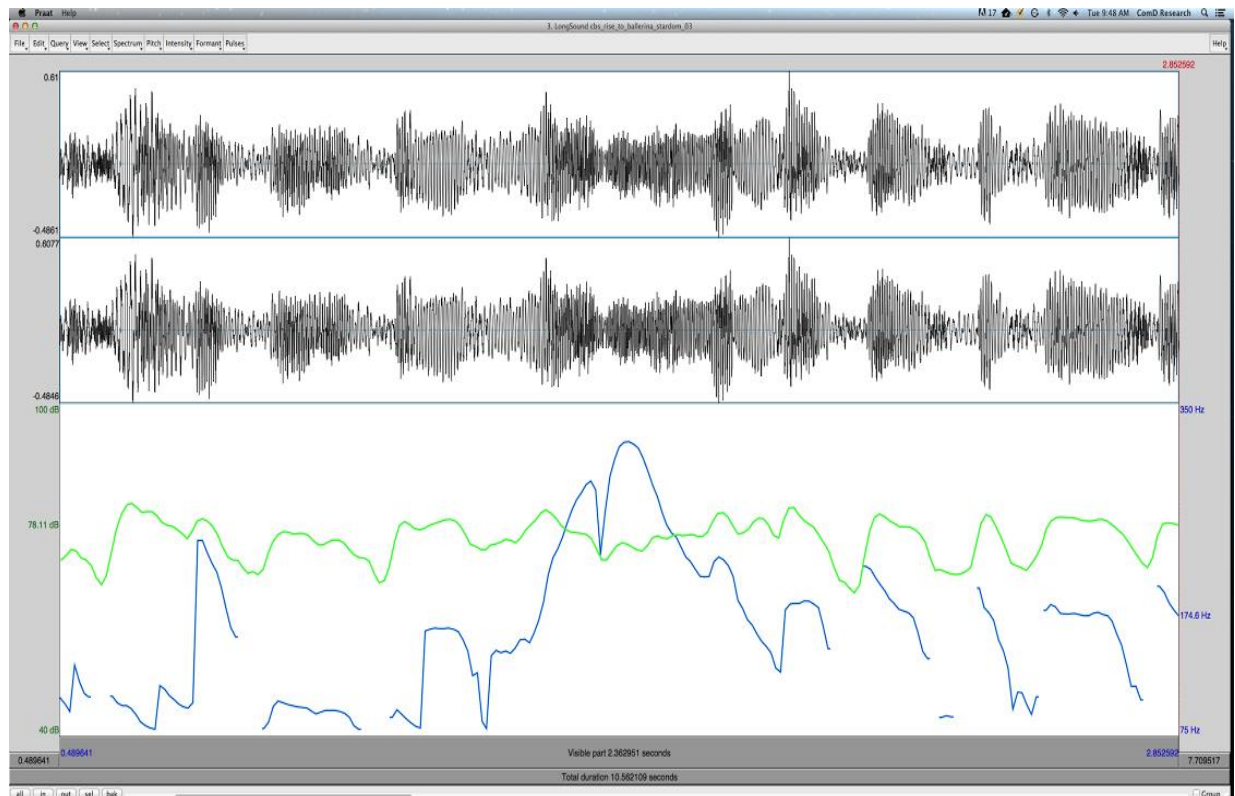
*Note.* Data collected from AphasiaBank

### *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).

### **Figure 1**

*Example of the Extracted Pitch Track (Blue Line) Using Praat Acoustic Software*



### ***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 a pitch 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 ensure reliability between researchers, 10% of the pitch and intensity measurement boundaries were measured by a second researcher. The utterances measured a second time were randomly chosen from across the four elicitation tasks and the 16 speaker recordings. For the pitch measurements, the first and second sets of ratings had a Pearson correlation of  $r = .93, p < .001$ .

### **Statistical Analysis**

Descriptive statistics were used to outline the central tendencies and variabilities in pitch and intensity measures. Differences as a function of the participants' aphasia status and the chronological location in the speech sample were examined using a Two-Way Analysis of Variance (ANOVA). The associations between the speakers' AQ, mean length of utterance, and the extracted pitch and intensity measures were evaluated through Pearson correlations.

## **Results**

### **Pitch Measures**

The pitch measure means and standard deviations as a function of location within the conversation and aphasia status of the participant can be found in Table 2.

**Table 2***Pitch Measures of Neurologically Healthy and Aphasic Participants*

Measure	Time <sup>a</sup>	Neurologically Healthy Participants		Aphasic Participants	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Pitch Average	1	150.35	44.68	166.38	44.83
	2	151.07	50.79	163.17	47.48
	3	151.82	47.18	172.38	44.08
	4	148.65	43.85	176.38	46.22
Pitch Variance	1	25.57	12.64	28.56	13.37
	2	31.44	14.00	27.01	8.61
	3	28.21	19.77	29.54	12.43
	4	26.11	10.61	34.61	16.49
Pitch Range	1	137.35	78.16	142.89	90.17
	2	168.92	90.12	132.40	63.53
	3	148.47	96.30	145.94	77.22
	4	144.79	64.30	165.43	105.24
Utterance Duration	1	3.92	2.50	4.41	3.00
	2	4.25	3.07	3.45	1.74
	3	4.19	3.10	4.46	2.44
	4	4.21	3.56	3.31	1.95

*Note.* <sup>a</sup> Time is coded according to where it occurs chronologically in the speech sample and each recording was divided into quadrants according to duration (i.e., beg to 25%, 25% to 50%, 50% to 75%, 75% to end).

**ANOVA**

The ANOVA indicated no significant main effects or interactions for any of the pitch measures (e.g., pitch mean, pitch variability, pitch range) as a function of the location of the utterance in the speech sample or the aphasia status of the speakers.

### ***Pearson Correlations***

A Pearson correlation revealed a significant association between the aphasic participants AQ and the pitch variability of their utterances ( $r = .34, p = .01$ ). Speakers with lower AQ scores were found to have lower pitch variability in their speech. As shown in Table 3, several significant associations were also found between the different pitch and intensity measures. For example, increases in the aphasic participants' pitch variability correlated to associated increases in their speech pitch range ( $r = .89, p = .01$ ) and intensity range ( $r = .31, p = .05$ ). Likewise, as the aphasic participants' pitch range increased, an associated increase was also found in their intensity variability ( $r = .27, p = .05$ ) and range ( $r = .42, p = .01$ ). In addition, it was interesting to find that as the length of the aphasic speaker's utterances increased, the pitch range ( $r = .39, p = .01$ ), intensity variability ( $r = .43, p = .01$ ), and intensity range ( $r = .52, p = .01$ ) also increased. While not a primary objective of this study, a Pearson correlation table was generated to explore the relationships between pitch and intensity in the neurologically healthy group. These findings are presented in Table 4.

**Table 3***Pearson Correlations for Pitch, Intensity, and WAB Aphasia Quotient in Aphasic Group*

Variable	1	2	3	4	5	6	7	8
1. Aphasia Quotient	-	.01	.34**	.12	.09	.20	.17	-.04
2. Pitch Average		-	.43**	.52**	.08	.07	.18	.03
3. Pitch Variability			-	.89**	.07	.21	.31*	.13
4. Pitch Range				-	.10	.27*	.42**	.39**
5. Intensity Average					-	.64**	.63**	.06
6. Intensity Variability						-	.95**	.42**
7. Intensity Range							-	.52**
8. Utterance Duration								-

Note. Pearson Correlation; \* $p < .05$  (blue), \*\*  $p < .01$  (green)

**Table 4***Pearson Correlations for Pitch and Intensity in Neurologically Healthy Group*

Variable	1	2	3	4	5	6	7
1. Pitch Average	-	.47**	.44**	.17	-.08	-.04	-.22
2. Pitch Variability		-	.83**	.03	.13	.17	.03
3. Pitch Range			-	-.06	.26*	.34**	.39**
4. Intensity Average				-	-.28*	-.23	-.23
5. Intensity Variability					-	.93**	.33**
6. Intensity Range						-	.45**
7. Utterance Duration							-

Note. Pearson Correlation; \* $p < .05$  (blue), \*\*  $p < .01$  (green)

## Intensity Measures

Table 5 displays the intensity means and standard deviations based on conversation location and participant aphasia status.

**Table 5**

*Intensity Measures of Neurologically Healthy and Aphasic Participants*

Measure	Time <sup>a</sup>	Neurologically Healthy Participants		Aphasic Participants	
		Mean	SD	Mean	SD
Intensity Average	1	64.77	8.43	54.26	7.48
	2	63.74	8.01	53.58	6.46
	3	63.90	8.81	53.93	6.57
	4	63.74	8.62	55.72	7.65
Intensity Variance	1	6.70	1.67	8.19	2.54
	2	6.69	1.19	7.42	2.36
	3	6.32	1.06	8.06	2.43
	4	6.74	1.51	7.77	2.04
Intensity Range	1	27.85	5.44	29.72	6.84
	2	27.16	4.73	27.51	7.44
	3	26.91	4.99	29.65	6.77
	4	27.38	4.98	28.68	5.68
Utterance Duration	1	3.91	2.50	4.17	3.00
	2	4.24	3.07	3.33	1.74
	3	4.18	3.10	4.51	2.47
	4	4.20	3.56	3.30	1.95

*Note.* <sup>a</sup> Time is coded according to where it occurs chronologically in the speech sample and each recording was divided into quadrants according to duration (i.e., beg to 25%, 25% to 50%, 50% to 75%, 75% to end).

## ***ANOVA***

No significant main effects or interactions were identified for any intensity measures across speech sample locations or participant aphasia status.

## ***Pearson Correlations***

The Pearson correlations demonstrated several significant associations in relation to intensity measures. As the participant's intensity average increased, the intensity variability ( $r = .67, p = .01$ ) and intensity range ( $r = .69, p = .01$ ) also increased. Likewise, as the participant's intensity variability increased, an associated increase in intensity range ( $r = .95, p = .01$ ) and intensity duration ( $r = .42, p = .01$ ) was observed. Additionally, as a participant's intensity range increased, the intensity duration ( $r = .52, p = .01$ ) was also found to be higher. Finally, as the participant's utterance increased in length, an associated increase was found in pitch range ( $r = .39, p = .01$ ), intensity variability ( $r = .42, p = .01$ ), and intensity range ( $r = .52, p = .01$ ). As shown in Table 3, additional associations were found between pitch and intensity measures.

## **Discussion**

This study analyzed measures of prosodic pitch and intensity in adults with aphasia compared to neurologically healthy adults, focusing on variations across task timing and AQ. The findings and their clinical implications are discussed below, addressing the research questions introduced earlier.

### **Aphasic Status**

The first aim of this study was to evaluate if individuals with moderate Broca's aphasia exhibit atypical patterns of speech pitch and intensity compared to neurologically healthy adult speakers of approximately the same age. The study found no significant prosodic differences in aphasic and neurologically healthy groups. One of the primary markers of Broca's aphasia is

dysprosody (Samuel et al., 1998). The term dysprosody may be problematic because it not only encompasses pitch and intensity, but also tempo and vocal quality (Shriberg & Kent, 2013). Although this study found no significant pitch and intensity differences between aphasic and control subjects, dysprosody could be denoted by impairments in the other elements, such as timing (Baum et al., 1997; Emmorey, 1987; Thomas, 2021). The etiology of Broca's aphasia may explain why pitch remained consistent with controls. Most commonly, Broca's aphasia is a result of a stroke in the dominant inferior frontal lobe or Broca's area (Fridriksson et al., 2014) resulting in an acquired language disorder affecting various aspects of the language system (Sheppard & Sebastian, 2020). Pitch is primarily produced from adduction of the vocal folds (Belyk et al., 2018); thus, pitch impairments is common in people with neuromuscular diseases, such as Parkinson's disease (Bowen et al., 2013). In most cases of Broca's aphasia, deficits are found in the motor planning stage, with rare effects on vocal fold tension.

Additionally, no significant differences in the various intensity measures were discovered between the aphasic group and the control group. This may also be explained by the motor planning deficits resulting from Broca's aphasia, rather than motor execution. Intensity is primarily a result of changes in subglottal and alveolar pressure (Zhang, 2016). However, impairments in respiration are not typically a symptom of Broca's aphasia.

Furthermore, the narrative retell task type may attribute to the lack of significant differences in pitch and intensity in participants with Broca's aphasia. Participants in the study were asked to recount the popular story of *Cinderella*, which may not have elicited a deep emotional response in the speaker. However, other task types, like the personal interview, may evoke greater emotion from the speaker.

### **Time of Task**

The second aim of the study was to evaluate if the pitch and intensity in speech samples of people with Broca's aphasia change during the time of the task (i.e., beginning, middle, and end). This study found no significant difference in any speech pitch and intensity measures during certain times of the task. Individuals who suffered a stroke commonly report fatigue, especially in attention and executive function tasks (Riley et al., 2019). However, the lack of changes in pitch and intensity throughout the speech sample contrasts with this assumption and may be explained by the short duration of the story retell task. Speech tasks of longer duration or requiring deeper cognitive load may fatigue the participant. Additionally, the story retell task is the third task out of four to be administered, according to the AphasiaBank protocol (MacWhinney et al., 2011). In the fourth task administered, patients may feel the most fatigue, which may affect speech pitch and intensity.

### **Aphasia Quotient Score**

Finally, the third research aim of the study examined whether the AQ score of the participant significantly correlated with pitch and intensity measures. This study found a significant correlation between AQ and pitch variability. The AQ score derives from four major areas of the WAB-R (Kertesz, 2006), including spontaneous speech, auditory comprehension, repetition, and naming; thus, a high AQ score indicates less severity in the test areas (Crary & Rothi, 1989). In this study, aphasic participants were classified with moderate Broca's aphasia, which corresponds to an AQ score of 51–75 (Lee et al., 2021). Pitch variability derives from intonation (Rodero, 2022). The positive association between AQ and pitch variability appears reasonable, as it suggests that patients with higher AQ scores tend to speak with more natural intonation. Interestingly, in this study the AQ score was not significantly correlated to other

measures. This may be explained by the lack of variability in the subjects with moderate Broca's aphasia, where each patient demonstrated similar speech patterns of halting, effortful speech, and reduced phrase length (Sheppard & Sebastian, 2020). It would be beneficial to further this research by utilizing subjects of larger classifications and severities of aphasia. Additionally, apraxia severity is likely contributing to the participants' AQ scores, as individuals with more severe apraxia may demonstrate reduced performance on fluency, repetition, and potentially naming subtests. Impaired prosody, including features such as excess and equal stress, is a hallmark of apraxia (Bislick et al., 2017). From this perspective, it is reasonable to expect that greater apraxia severity would be associated with decreased pitch variability.

Although not a specified aim of the study, correlations were also conducted between various pitch measures. Several significant correlations between measures were found, including a positive connection between utterance duration and pitch range, intensity range, and intensity variability. Interestingly, no significant correlation was observed between utterance duration and pitch variability. This may be attributed to the generally shorter utterances produced by individuals with Broca's aphasia (Sheppard & Sebastian, 2020), making it challenging to accurately assess pitch variability in such brief speech samples.

### **Limitations of the Current Study**

There are several limitations of the current study. One suggestion for future research is to study prosodic measures from speech samples of different task types, such as personal interview, picture description, and personal narrative. This could reveal how individuals with Broca's aphasia produce speech under different emotional and cognitive demands. Another limitation to the current study was the relatively small sample size of 16. The reliability and validity of the WAB was first established with an experimental group of 150 aphasic individuals (Shewan &

Kertesz, 1980). Thus, an increased sample size would be beneficial to draw more accurate applications. Finally, a limitation of the current study is the imprecision in collecting intensity measures. Although all recordings were conducted using the same protocol, it may be beneficial to have recorded all the speech samples in the same location using the same recording equipment. To alleviate these concerns, it may also be beneficial to normalize the intensity values as a function of relative difference from the recording noise floor.

### **Conclusions**

Although this study has limitations, its findings offer valuable insights into the complexities of prosody in individuals with Broca's aphasia. A deeper understanding of prosody in this population can aid clinicians in developing more effective assessment tools and treatment approaches. These advancements have the potential to enhance communicative effectiveness, enabling individuals with Broca's aphasia to build meaningful relationships, pursue educational and career opportunities, and actively engage in their communities.

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## APPENDIX A

**Annotated Bibliography**

Cherney, L. R., Kiran, S., Haley, K. L., Holland, A., Schwartz, M., Kagan, A., & Simmons-

Mackie, N. (2018). Survey of aphasia assessment measures implemented in clinical and research settings. *Archives of Physical Medicine and Rehabilitation*, 99(10), e42.

<https://doi.org/10.1016/j.apmr.2018.07.145>

*Objective:* The aims of this survey was to gather information about aphasia assessment in different clinical and research settings. *Method:* A Qualtrics study was created, and sent to the entire AphasiaAccess membership, ASHA Division 2, and ASHA community SLP Healthcare Listservs. This study had 109 respondents complete the survey. The survey asked the respondents what assessment measures they used for clinical or research evaluations. In addition, it also asked which measures they used to describe patients and their success and progress. The survey also asked if the respondents made any modifications to the assessment or used any informal measures from the assessment.

*Conclusions:* The respondents worked in a wide variety of settings including intensive aphasia program, clinical inpatient/outpatient/home setting, aphasia center, aphasia research center, and unspecified research/clinical centers. The most common aphasia assessment used was the Western Aphasia Battery-Revised (WAB-R). The Boston Naming Test (BNT) followed in popularity. In addition, the Cognitive Linguistic Quick Test (CLQT) and the Communicative Effectiveness Index (CETI) were also regularly administered tests. The respondents also regularly made a variety of modifications to the assessment. This included: (a) repetition of stimuli, (b) rephrasing stimuli, (c) using additional cueing, (d) adding pictures to understand the assessment questions, (e)

changing assessment administration, (f) modifications to Likert scales, (g) administering specific subtests, and (h) translating test material. *Relevance to current study:* This is relevant to my current study because it describes the assessment material provided for people with aphasia. It indicates that clinicians do not alter their assessments to include prosodic measures.

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.

Fox Tree, J., & Meijer, P. (2000). Untrained speakers’ use of prosody in syntactic disambiguation and listeners’ interpretations. *Psychological Research, 63*(1), 1–13. <https://doi.org/10.1007/p100008163>

*Objective:* This study aimed to study how untrained speakers produce ambiguous sentences, and listener's interpretations of these sentences. The study consisted of three experiments. Experiment 1 asked listeners to choose the context the ambiguous sentence derived from. Experiment 2 asked listeners to paraphrase the sentences. Experiment 3 aimed to understand the extent to which people rely on prosody to interpret meaning.

*Method:* In Experiment 1, six speakers produced twelve ambiguous sentences. Thirty-six subjects were then asked to listen to the ambiguous sentences and assign the correct written sentence to it. In Experiment 2, 19 subjects were asked to listen to the speech stimuli, and paraphrase it in context. In experiment 3, the speech samples from experiment 1 were spliced. Thirty-six subjects were asked to answer questions about these new speech samples. *Conclusions:* Experiment 1 found that listeners could not accurately judge which context went with the speech stimuli (on average, getting 51% correct). Experiment 2 found that listeners can pick up on prosodic elements of the speech sample. Experiment 3 showed that listeners ignored evaluating prosody when the context of the sentence is available. *Relevance to current study:* This is relevant to my study because it indicates that the context of sentences are more important than the prosody of the sentence for people with aphasia.

Gasser, E., Ahn, B., Napoli, D. J., & Zhou, Z. (2019). Production, perception, and communicative goals of American newscaster speech. *Language in Society*, 48(2), 233–259. <https://doi.org/10.1017/s0047404518001392>

*Objective:* This study aims at explaining why broadcast news reporters sound 'different'. It looks at the pitch, speed, intensity, and melodic features of the speech of newscasters compared to conversational speech. In addition, the study also aims at classifying the

perception of newscaster speech. *Method:* In the first experiment, 12 sentences were recorded by newscasters. Those 12 sentences were also recorded by non-newscaster volunteers. The recordings were measured by speech rate, recording length, intensity variation, pitch range, and mean pitch. In experiment 2, 481 participants classified if 18 speech samples were said by a ‘newscaster’ or ‘everyday speech.’ The speech samples were filtered, so that the participants could not understand individual words.

*Conclusions:* Experiment 1 found that newscasters spoke slower than the conversational volunteers, had less variation in intensity, had a lower minimum pitch, and spoke most typically in their middle and highest quartile of their pitch range. Experiment 2 found that participants were able to classify the newscaster speech at a rate better than chance.

*Relevance to current study:* This applies to my study about people with aphasia and prosodic features. It shows that listeners can perceive differences in the type of speaker with only relying on prosodic elements.

Goodglass, H., Barresi, B., Weintraub, S., & Kaplan, E. (2001). *The Boston Diagnostic Aphasia Examination, Third Edition (BDAE-3)*. Lippincott Williams & Wilkins.

*Objective:* The BDAE consists of 8 subtests: fluency, auditory comprehension, naming, oral reading, repetition, automatic speech, reading comprehension, and writing. The purpose of the BDAE is to measure and distinguish aphasia, and to classify its characteristics. *Relevance to current study:* This is an assessment that can be used to assess and diagnose people with aphasia.

Gregory, S. W., & Gallagher, T. J. (2002). Spectral analysis of candidates’ nonverbal vocal communication: Predicting U.S. presidential election outcomes. *Social Psychology Quarterly*, 65(3), 298–308. <https://doi.org/10.2307/3090125>

*Objective:* This study looks at non-verbal elements (including fundamental frequency) of candidates from 19 televised U.S. Presidential debates. It aims at classifying the most dominant prosodic elements, and it predicts the popular vote outcomes in the subsequent elections accurately. *Method:* This study looked at 19 U.S. presidential debates over 9 elections. For each of the 16 candidates, nine speech samples were analyzed using a Fast Fourier Transform (FFT). The acoustic analyses were compared to the popular vote poll results. *Conclusions:* This study found that the candidates with fundamental frequencies below .5kHz are perceived with relative dominance. This prosodic element accurately predicted the outcomes for the popular poll. *Relevance to current study:* This study emphasized the point that prosodic elements in speech (specifically pitch) alters how the speaker is perceived. This can apply to my study about people with aphasia and prosody because it shows that people with aphasia might be perceived less dominant or commanding due to their altered prosody.

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.

Kleinow, J., Smith, A., & Ramig, L. O. (2001). Speech motor stability in IPD. *Journal of Speech, Language, and Hearing Research*, 44(5), 1041–1051. [https://doi.org/10.1044/1092-4388\(2001/082\)](https://doi.org/10.1044/1092-4388(2001/082))

*Objective:* Lee Silverman Voice Treatment (LSVT) utilizes increased loudness as a strategy for adults with hypokinetic dysarthria resulting from Parkinson's disease. This study compares the results of louder speaking to speaking rate, which is another treatment for hypokinetic dysarthria. *Method:* Group IPD consisted of eight adults who were diagnosed with idiopathic Parkinson disease. Group CONT-A included eight healthy participants and group CONT-Y included eight adults with age range of 21 to 28. The participants repeated the phrase "Buy Bobby a puppy" in five different conditions (habitual, fast, slow, loud, and soft). Spatiotemporal index (STI) was measured to identify stability in the motor movements. *Conclusions:* Slower speech rates were connected to more variability in trajectory movements, whereas greater intensity was connected to less variability in trajectory movements, indicating greater stability. *Relevance to current study:* This can be a treatment plan used to increase loudness in people with aphasia.

Ladd, D. R. (1988). Declination "reset" and the hierarchical organization of utterances. *The Journal of the Acoustical Society of America*, 84(2), 530–544.

<https://doi.org/10.1121/1.396830>

*Objective:* This study looked at the fundamental frequency of sentences of form "A and B but C" and "A but B and C" (where A, B, and C are clauses). *Method:* The sentences were recorded, and the pitch peaks were calculated. *Conclusions:* This study found that pitch accent peaks were higher following the word "but" rather than "and." *Relevance to current study:* This is relevant to my study about the prosody of people with aphasia because it classifies the typical pitch contours of people without aphasia.

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:* This study aims at illustrating the difficulties that people with left hemisphere damage have when using and perceiving affective prosody. *Method:* This study utilized 11 participants with left hemisphere dysfunction and 15 control participants. To measure their ability to perceive affective prosody, the subjects listened to 12 audio recordings and chose the facial photo that matched. They also listened to 12 more audio recordings and chose photos of scenes that matched. To measure their ability to produce prosody, the subjects were asked to perform tasks including: repetitive monosyllabic, spontaneous monosyllabic, and spontaneous word/sentence tasks. Their responses were recorded and analyzed in the following ways: fundamental frequency, frequency range, minimum frequency, maximum frequency, and standard deviation for frequency. *Conclusions:* The control group scored higher than the experimental group for the perception task. The control group had much greater variability in pitch range (stroke:183.21 Hz, control 228.65 Hz.) *Relevance to Study:* This relates to my study because it quantifies the prosodic differences between people with aphasia and people without aphasia.

Menses, J., & Díaz, J. (2017). Vocal Emotion Expressions Effects on Cooperation Behavior. *Psicológica, 38*, 1–24.

*Objective:* Understanding emotions in social interaction is beneficial to interpret behavioral intentions. This study researches emotion and its effects on desired cooperation through the vocal emotional expressions, rather than facial emotional expressions. *Method:* Forty-eight undergraduate students listened to 60 variations of the

phrase, “let’s play”, where each phrase was said with joy, anger, or a neutral expression. The phrase was filtered, and the phonemic information was masked, so participants had to rely on prosodic elements. The participants were asked to choose the emotion that best described the recording (joy, anger, sadness, fear, disgust, or neutral). In addition, participants chose if they would cooperate or defect based on the speech sample.

*Conclusions:* Because the speech samples featured the same words, participants relied on the prosody of the speech to interpret their emotion. This study found that prosody influences social cooperation. *Relevance to current study:* This study found that prosody can influence cooperation. For people with aphasia, they might experience difficulty with gaining cooperation from their peers when they fail to vary prosodic elements.

Niebuhr, O., Brem, A., & Tegtmeier, S. (2017). Advancing research and practice in entrepreneurship through speech analysis – From descriptive rhetorical terms to phonetically informed acoustic charisma profiles. *Journal of Speech Sciences*, 6(1), 3–26. <https://doi.org/10.20396/joss.v6i1.14983>

*Objective:* Charisma appeals to listener’s feelings and attitudes. This study aimed at quantifying prosodic elements in speech that convey charisma, in order for these features to be trained to entrepreneurs. *Method:* The researchers gathered 20-25-minute speech samples from entrepreneurs who are either recognized for their charisma or their lack thereof. The speech samples were analyzed by pitch, pitch range, speech rate, and intensity, among other aspects. *Conclusions:* Steve Jobs was perceived to be a master of charismatic and persuasive speaking, whereas Mark Zuckerberg lacked this ability. In speech samples of Jobs and Zuckerberg, Jobs displayed a higher pitch level, larger pitch range, and greater rhythmic variability. Zuckerberg displayed greater intensity in his

voice, the only charismatic acoustic feature that outperformed Jobs. *Relevance to current study*: This brings greater application to the importance of prosody in speech. This study quantified how prosody does impact entrepreneurs and their ability to persuade consumers to buy their products. This can help people with aphasia and their ability to perform their job effectively.

Rhys, C. S., Ulbrich, C., & Ordin, M. (2013). Adaptation to aphasia: Grammar, prosody and interaction. *Clinical Linguistics & Phonetics*, 27(1), 46–71. <https://doi-org.byu.idm.oclc.org/10.3109/02699206.2012.736010>

*Objective*: This study aims at determining how a patient with severe nonfluent aphasia can alter one automatic phrase to produce a variety of interactional and expressive meaning. *Method*: This study analyzes the recurrent utterance of very good in a speaker with nonfluent agrammatic Broca's aphasia (Maeve). The phrases are analyzed to decipher the different interactional uses of the phrase and to determine the temporal and fundamental frequency elements of the phrase. *Conclusions*: It was found that prosody was altered in her utterances; however, there was no significant connection to pitch contours and the variants of very good. Maeve's variants of the utterance also rely on turn taking and syntax. *Relevance to current study*: This relates to my study because it is important to understand how pitch changes in automatic utterances of people with aphasia.

Rodero, E., Mas, L., & Blanco, M. (2014). The influence of prosody on politicians' credibility. *Journal of Applied Linguistics & Professional Practice*, 11(1), 89–111. <https://doi.org/10.1558/japl.32411>

*Objective:* This study aimed at discovering how prosody affects credibility, specifically in the perception of a politician's credibility. *Method:* This study looked at presentations given by three politicians (Ana Botella, Ali Babacan, and Naoki Inose). The sound samples were analyzed by PRAAT to calculate the speaker's loudness, pitch level, pitch range, intonation contours, speech rate, and pause. In addition, the speeches were analyzed to see how prosody marked each word and sentence, using the Wichmann's structure of discourse. These speech samples were then presented to a sample of 110 adults who did not speak the language of the speakers, and they judged each speaker on a credibility scale. *Conclusions:* Babacan was deemed the most credible speaker. His speech had the highest loudness, a varied pitch range, fast speech rate, and ample pauses. *Relevance to current study:* This is relevant in my study because it supports that prosody does affect the credibility of speakers, including the credibility of people with aphasia.

Rosenberg, A., & Hirschberg, J. (2005). Acoustic/prosodic and lexical correlates of charismatic speech. *Interspeech 2005*, 513–516. <https://doi.org/10.21437/interspeech.2005-329>

*Objective:* Charisma is identified by the ability to command authority and persuade due to personal virtue. This study aims at finding the connection between perceived charismatic voices and their acoustic and prosodic elements, including their interactions with lexical and syntactic forms. Overall, they aim to label empirical data to the definition of charisma. *Method:* Eight American English Speakers were asked to listen to 45 speech segments of politicians between two and 28 seconds. The speech segments limited these politicians to come from the Democratic party, to reduce the amount of variability in preference for their beliefs. In addition, the speech segments focused on neutral topics to reduce the variability. The listeners were asked to list their agreement

with 26 statements about the audio. The questions included: “the speaker is X,” where X was charismatic, angry, passionate, etc. *Conclusions:* A kappa statistic determined that the results suggest low agreement and some variation in the ratings of the 26 statements. There is high agreement in inter-annotator ratings. It was found that five statements held a consistent positive correlation to the charismatic speaker’s voice. This includes enthusiastic, charming, persuasive, passionate, and convincing. A speaker that spoke more words was more likely perceived as charismatic. There is no connection between the amount of function words (prepositions and determiners) to content words (nouns and verbs) and the perception of charisma. Charismatic speakers also produced more first-person pronouns. Speech samples with more complex words were rated more as charismatic. The speech samples that were rated as charismatic also had the greatest mean and standard deviation of fundamental frequency. This study also found that louder messages convey charisma. *Relevance to current study:* This can be applied to my study because it shows that a greater standard deviation (like pitch variability in enthusiastic and expressive speakers) indicates greater charisma. For people with aphasia, it is important to note a dynamic intonation will make listeners perceive them as charismatic. In addition, some people with aphasia speak softly, which might make them sound less charismatic.

Sheppard, S. M., & Sebastian, R. (2020). Diagnosing and managing post-stroke aphasia. *Expert Review of Neurotherapeutics*, 21(2), 221–234.

<https://doi.org/10.1080/14737175.2020.1855976>

*Objective:* This paper outlined the traditional classification approach in aphasia and also discussed behavioral treatment approaches. About 1/3 of people who have strokes acquire

aphasia, an “acquired language disorder where patients experience impairments of various aspects of their language system (i.e., phonological, morphological semantic, syntactic, and/or pragmatic)” (Sheppard & Sebastian, 2021, p. 1). Traditional aphasia classification is based on fluency, comprehension, and repetition. Fluent aphasia consists of Wernicke’s, transcortical sensory, conduction, and anomic aphasia. Nonfluent aphasia consists of global, mixed transcortical, Broca’s, and transcortical motor. Specifically, Broca’s aphasia is distinguished by “halting, effortful, non-fluent speech that has reduced phrase length, impaired melody, and diminished words per minute” (Sheppard & Sebastian, 2021, p. 3) *Relevance to current study*: This is relevant to my current study because it defines what aphasia is, outlines the classification system, and delves into assessment and treatment for aphasia.

Waber, B., Williams, M., Carroll, J. S., & Pentland, A. (2011). A voice is worth a thousand words: The implications of the micro-coding of social signals in speech for trust research. In F. Lyon, G. Möllering, & M. N. K. Saunders (Eds.), *Handbook of Research Methods on Trust*. (Chapter 23, Business 2011 Collection). Edward Elgar Publishing eBooks. <https://doi.org/10.4337/9780857932013.00033>

*Objective*: Computers can code the non-linguistic elements of a conversation and capture it in real time. This is applicable for areas of medicine. This study aims at finding the benefits and challenges of using a computer to analyze the prosodic elements of a conversation in medical conversations. It coded activity level, conversational engagement, prosodic emphasis, and vocal mirroring. *Method*: The study looked at multiple elements of a speech sample where an employee and boss were calculating salary levels. *Conclusions*: It found that the computer could predict 30% of the variance

of the final salaries. *Relevance to current study:* Overall, this study emphasizes that non-linguistic elements of speech can predict later outcomes. This validates the importance of understanding more about the prosody of people with aphasia because it can lead to differing outcomes.

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:* This study investigated the left hemisphere contribution to linguistic prosody in three different linguistic settings, including lexical stress in nouns vs. verbs, compound nouns vs. tag constructions, and echo questions vs. statements. It also evaluated the degree in which naive listeners could understand the meaning behind the utterances produced by people with left hemisphere damage. *Method:* The study consisted of three experiments. Experiment 1 analyzed the production of lexical stress differences in nine LHD subjects and 10 control subjects. They were given ten noun/verb pairs of two syllable words; typically, the first syllable of nouns is stressed, whereas the second syllable of verbs are typically stressed. Experiment 2 analyzed the production of prosodic elements in the face of syntactic boundaries (like commas in a sentence). Experiment 3 analyzed the production of prosodic elements when given a statement and a question. The subjects were shown the pictures and words and asked to say the words out loud. The study measured the average duration, fundamental frequency, and amplitude of the paired words. Naive listeners were presented with the words or pictures and asked to select the item that matched with the subject's verbal response. *Conclusions:* Naive listeners had more difficulty understanding the meaning of the utterances produced by the subjects

with left hemisphere damage; this suggests that the left hemisphere has a role in forming linguistic prosody. *Relevance to current study*: This relates to my study because it suggests that people with aphasia have altered pitch.

Wilson, S. M., Eriksson, D. K., Schneck, S. M., & Lucanie, J. M. (2018). A quick aphasia battery for efficient, reliable, and multidimensional assessment of language function. *PLoS ONE*, *13*(2), e0192773. <https://doi.org/10.1371/journal.pone.0192773>

*Objective*: This article describes a Quick Aphasia Battery (QAB) that aims to assess the language of people with aphasia in a quick fashion. It has eight subtests including: (a) level of consciousness, (b) connected speech, (c) word comprehension, (d) sentence comprehension, (e) picture naming, (f) repetition, (g) reading aloud, and (h) motor speech. *Relevance to current study*: The QAB is relevant to my study because this test can assess the abilities of people who had left hemisphere damage.

Zougkou, K., Weinstein, N., & Paulmann, S. (2017). ERP correlates of motivating voices: quality of motivation and time-course matters. *Social Cognitive and Affective Neuroscience*, *12*(10), 1687–1700. <https://doi.org/10.1093/scan/nsx064>

*Objective*: This study looked at how motivational and neutral tones expressed through speech are processed in the brain. This study also sought to measure how different types of motivational tones (supportive-autonomy and controlling) affect brain processing. The motivational speech samples differ in prosody and word content. *Method*: This study asked 20 English speakers to closely listen to 100 speech stimuli while their EEG recordings were obtained. The speech stimuli varied in five ways: “(1) sentences expressing autonomy-support through prosody and word use; (2) sentences expressing control through prosody and word use (3) semantically neutral sentences intoned with a

non-motivational, neutral tone of voice; (4) semantically neutral sentences spoken in an autonomy-supportive prosody; (5) semantically neutral sentences spoken in a controlling prosody” (p. 1690). *Conclusions*: This study found that speech stimuli with motivational aspects are processed within 200 milliseconds of onset. The speech stimuli with controlling prosody, rather than autonomy-supportive prosody are evaluated with greater precision. However, they found if the word content of the speech stimuli has a forceful call to action, the type of prosody does not matter. *Relevance to current study*: This study confirms the idea that types of prosody are processed differently in the brain. This is relevant to my study because it shows that the type of prosody that people with aphasia use is important for listener processing and awareness.

## 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](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 deidentification, 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 identifying 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](#).

## APPENDIX C

**Consent Form****RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM  
AphasisBank****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.

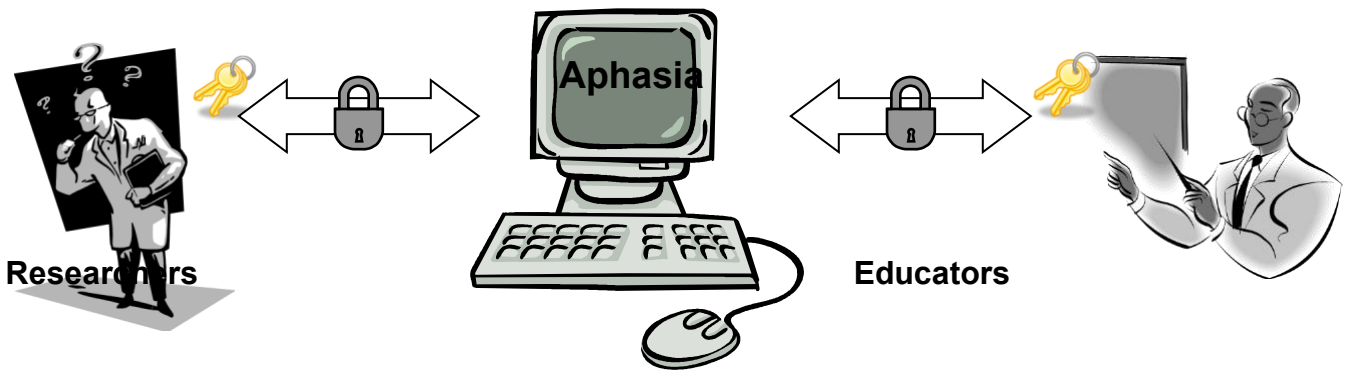


### USE

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.



### RISKS

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.

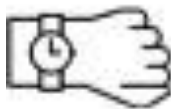


We can give you your test results for your files.

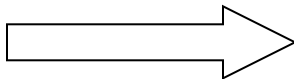


**TIME**

It will take 2 to 3 hours.



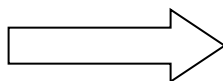
If you get tired, we can stop and finish another day.

**RIGHTS**

Your participation is voluntary.



??



Yes?



No?



??

You can stop at any time.





**Questions about the study:**

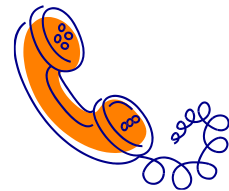
Contact  
Gretchen Szabo  
at  
201-368-8585  
or

[gszabo@adleraphasiacenter.org](mailto: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