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ACOUSTIC PHONETIC CHARACTERISTICS OF DISORDERED VOWELS

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ABSTRACT

In most acoustic phonetic studies, researchers go to great lengths to specify that the participants do not have any speech impediments. These specifications are meant to show that the speech patterns of the talkers qualify as mainstream pronunciation. This is not the case in this study. Author 2 has a noticeable speech impediment. She enrolled in Author 1's acoustic phonetic course. In this course, students study their own speech patterns in the minutest of details and compare their speech with that of a group of native or nonnative speakers. We do the same with Author 2's vowels to see how they resemble or differ from those produced in Central Minnesota, her dialect area.

Keywords: Disordered Vowels, Speech Impediment, Deaf Accent, Disordered Vowel Space, Acoustic Correlates of Disordered Vowels, Masking Analysis, Just Noticeable Difference (JND)

1.0 Introduction

It has become customary since Peterson and Barney (1952) to extract vowel features and compare them with those of other speakers. Hallenbrand et al. (1995) did so for Midwest speakers. Hagiwara (1997) compared the characteristics of vowels produced by southern Californians. Since 2013, Author 1 has been publishing papers on the vowels of Central Minnesota speakers. In all these previous studies, the participants do not suffer from any speech impediment(s). Rarely do researchers provide raw acoustic phonetic data on vowels produced by people with a speech impediment. Yet, this is a large population from which data ought to be made available. This is exactly what we are doing in describing the vowels produced by Author 2. We will get acquainted with the acoustic correlates of her vowels in four installments. In the first installment, Author 2 describes what her impediment is and the strategies that she has acquired since childhood to cope with it. The second installment discusses the elicitation task from which the data was collected. The third installment focuses on the measurements. The fourth and final installment highlights the similarities and differences between her vowels and those produced by central Minnesotans who do not suffer from any speech impediment.

2.0 Speaker's Bio

My name is Paige Gerlach, I am 20 years old at the time of the recording, and my native language is English. I was born and raised in Central Minnesota and learned English from birth with a naturalistic approach. I have been told by peers that my speech does not sound like I have a Minnesotan accent, or even any accent. There are two main reasons for this perception: hearing loss and a stutter[2], as these have had an impact on my speech production and speech

[1]**Authorship responsibilities:** The idea of writing on this topic originated with Author 1 from the acoustic phonetics course that Author 2 took from him in spring 2022. Author 1 bears full responsibility for any analytical or interpretive errors in this publication because he is the principal author. To the extent that the measurements provided by Author 2 are accurate, they both share equally in the rights, privileges, and responsibilities of this publication.

[2]Stuttering is categorized as a fluency disorder and characterized by "abnormal interruptions of speech (blocks, repetitions, and prolongations) which interfere with the smooth flow of speech" (Guitar, 2019, p. 8).

perception/comprehension. In the following paragraphs below, Author 1 and I will explain further how the nature of my hearing loss and stuttering affect my speech production.

2.1 Description of Speech Impediment and Coping Mechanisms

Phonemes or groups of phonemes may be lengthened in duration, lose voicing, or be repeated during stuttering episodes. Phonemes may also be less articulated, and sound mumbled during moments of stuttering. If one were to look at the prosodic prominence in my speech, it may look atypical when compared to the expected results because stuttering can alter pitch (make it higher), intensity (make it louder), or duration (make it longer). For reference, **repetitions** would look like this <r-r-ro-round> orthographically. Here a segment is attempted several times before the word finally comes out. For **prolongation**, the initial segment is lengthened before the word finally comes out, as in <rrrround>. **Blocks** are when there is obvious silence, even though the word is attempted, as in <_!_round>. The symbol "_!_" is used to symbolize blocks. From the standpoint of articulatory phonetics, blocks are best described as being stuck and having high amounts of tension in the articulators throughout speech production. Although, I do not stutter in the production of all utterances, **suppression techniques** and **acquired habits** influence my speech. These are escape and avoidance behaviors that I have developed over time. These techniques include eye blinking, facial grimace, avoiding eye contact, rocking back-and-forth on my feet, and more. These strategies come and go with the severity of my stuttering. For example, I rocked back-and-forth on my feet more in middle school than high school. In other words, I use various techniques to try and distract myself from whatever it is that I am saying, in hopes of more fluent speech production.

2.2 Speech Intelligibility

The intelligibility of my speech varies based on the severity of my stuttering, whether I have my cochlear implants on or not, and how long I have gone without wearing my implants. The longer I go without wearing my cochlear implants the worse my speech intelligibility gets. I mumble, I do not articulate clearly, or I speak too softly or too loudly. In such instances, my prosody becomes monotonous. This way of speaking is recognized as a **"deaf accent."** Sometimes, I do not voice the beginning or end of words even if my lips are making the correct phoneme production shape. All this happens because I cannot hear myself without my cochlear implants on. In such instances, I cannot evaluate my speech production the same way as someone with unremarkable hearing would. Normally, people monitor their speech by listening to two "voices": their "**outer voice**," which is heard by the listener(s), and their "**inner voice**"[3] that is only heard by the speaker. This means that, because of the nature of my hearing loss, I cannot hear the outer voice without my cochlear implants on and must rely on the "inner voice" to determine the intelligibility and social appropriateness of my voice/speech. When my implants are not on, I pay close attention to how fast or how slow my speech is. I prioritize duration and rhythmicity because it is easier to lip read the duration of a word than its intensity or pitch. When my implants are on, I rely more on intensity than duration for intonation. Thus, it can also be said that because of my hearing loss my brain is hardwired to fill in the blanks to complete a sentence before it takes intonation into account, leaving intonation as an afterthought for speech comprehension.

[3]Resonance and vibrations of the vocal folds internally felt by the speaker.

3.0 Elicitation Paragraph

Now that I have described my stutter and my associated coping mechanisms, let's turn our attention to the elicitation paragraph from which the relevant correlates were extracted:

> *Please call Stella. Ask her to bring these things with her from the[1] store: Six good spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a foot-long sandwich as a snack for her brother Bob. We also need a small plastic snake, the[2] little yellow book, a rubber duck, and a paper I-pad. She should not forget the[3] dog video game and the big toy frog for the kids. She must leave the faked gun at home but she may bring the[4] ten sea turtles, the mat that my mom bought, and the black rug. She can scoop these things into three red bags and two old backpacks. We will go meet her, Sue, Jake, and Jenny Wednesday at the very last train station. The station is between the bus stop and the cookie store on Flag Street. We must meet there at 12 o'clock, for sure. The entrance is at the edge of the zoo in Zone 4 under the zebra sign. York's Treasure Bank is the tall building in the left corner. She cannot miss it.*

This elicitation text is an expanded version of the text of the Speech Accent Archive (SAA). Author 1 augmented it because the SAA text accidentally omitted the "foot" vowel /ʊ/. The students who enroll in Author 1's class record themselves reading this paragraph even before they know what the course is really about. They are asked to read this elicitation paragraph as naturally as possible. Then during the semester, they do various projects based on the recording. Project 2 in the course focuses on extracting various acoustic correlates from the vowels, as indicated in Table 1:

Vowel Sounds and Names										
fleece	kit	face	dress	trap	lot	cloth	goat	goose	comma	letter
[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[u]	[ə]	[ɚ]
Words and Representative Vowels										
please	thick	maybe	Stella	ask	Brother	small	snow	spoons	the1	her1
peas	big	snake	fresh	slabs	Bob	call	also	blue	the2	her2
cheese	kids	station	red	bags[4]	frog	also	go	scoop	the3	her3

Table 1: List of Representative Vowels

Author 2 read the text and extracted seven correlates (F0, F1, F2, F3, F4, intensity, and duration) from each vowel. Each vowel occurs three times. So, the total number of tokens extracted for this paper is 252 (12 vowels x 7 correlates x 3 repetitions).

4.0 Correlate Extraction and Comparisons

The goal of this project is to evaluate how students' measurements compare with those of other speakers of American English. Most of the students who enroll in the course are from Central Minnesota. So, they compare themselves with speakers from this region. However, we have data from the Midwest (Hillenbrand et al. 1995), or from California (Hagiwara 1977), or from the General American English (Peterson and Barney 1952) with which students from other states can compare themselves. Peterson and Barney (1952) is used sparingly because, as noted by Ladefoged and Disner (2012:43), their measurements represent an old-fashioned dialect that

[4] Due to dialectal variations, some speakers may produce the <a> in <bags> as a "dress" vowel.

nobody speaks anymore. Since Author 2 is from Central Minnesota, she compared herself to the data in Table 2 that Author 1 has been compiling for nearly two decades. The acronym CMNE stands for Central Minnesota English. CMNE averages are based on data obtained from 17 college-aged females.

Words		**fleece**	**kit**	**face**	**dress**	**trap**	**lot**	**cloth**	**goat**	**foot**	**goose**	**strut**	**letter**
Vowels		[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]	[ɚ]
CMNE	F0	205	209	196	209	199	168	190	222	214	221	196	219
PAIGE	F0	288	289	274	222	238	217	200	246	233	250	255	237
CMNE	F1	404	485	462	636	821	780	577	526	547	427	674	542
PAIGE	F1	513	546	642	658	714	621	629	558	558	482	645	519
CMNE	F2	2434	1948	2374	1661	1731	1382	1325	1269	1459	1557	1577	1615
PAIGE	F2	2103	1922	1984	1344	1406	1137	1464	1294	1494	1349	1454	1740
CMNE	F3	2974	2755	2838	2537	2608	2575	2397	2919	2847	2794	2559	2128
PAIGE	F3	2887	2833	2766	2663	2690	2263	2212	2551	2646	2729	2498	2828
CMNE	F4	3766	3414	3230	3288	3447	3481	3490	3757	3757	3837	3515	3802
PAIGE	F4	2941	3772	3775	3627	3852	3409	3393	3578	3828	3817	3668	3821
DUR		156	97	127	82	160	187	116	124	108	177	138	112
PAIGE		260	162	311	230	231	291	308	203	293	244	167	87
DIFF		104	65	184	148	71	104	192	79	185	67	29	25
Intensity		55	55	54	58	57	57	54	55	57	55	56	61
PAIGE		63	65	64	68	65	66	65	66	66	66	69	67
DIFF		8	10	10	10	8	9	11	11	9	11	13	6

Table 2: Extracted Vowel Correlates

4.1 Masking and Intelligibility

Masking or lack thereof helps to determine whether or not two or more speakers produce the same speech sound similarly or differently. Ideally, the vowels of speakers from the same dialect should mask (be similar) to each other. Decades of acoustic phonetic investigations have helped to uncover Just Noticeable Difference (JND) thresholds for masking on various frequency bandwidths. Here, we are interested in F1 and F2 because they are the ones that matter most for the intelligibility and accentedness. These JNDs are stated as follows:

JND in the F1 Domain

If two or more speakers of the same dialect produce the same vowels, the acoustic distance between pairs of similar vowels should be ≤ 60 Hz on the F1 frequency bandwidth. Otherwise, intelligibility problems may arise (Koffi 2021a:38).

JND in the F2 Domain

If two or more speakers of the same dialect produce the same vowels, the acoustic distance between pairs of similar vowels should be ≤ 200 Hz on the F2 frequency bandwidth. Otherwise, their vowels are accented (Koffi 2021a:38).

These JNDs are the yardstick with which the different vowels produced by Author 2 are compared with the ones produced by her CMNE counterparts.

4.2 Masking on the F1 Frequency Bandwidth

Only 61 Hz separates Author 2's [ɪ] (546 Hz) from [ɪ] (485 Hz) in CMNE. We conclude that these two vowels mask each other, i.e., they are auditorily identical. The F1 measurements in Table 2 show that 8 of Author 2's 12 vowels are similar to those produced by CMNE speakers. These vowels are [ɪ, ɛ, ɔ, o, ʊ, u, ʌ, ɚ]. Four vowels, namely, [i, e, æ, ɑ] do not mask each other, which means that, Author 2 produced them differently than her CMNE counterparts. Her [i] (513 Hz) is different from [i] (404 Hz) in CMNE by 109 Hz. Her [e] (642 Hz) and [e] (462 Hz) in CMNE are dissimilar by 180 Hz. Her [æ] (621 Hz) is different from [æ] (821 Hz) in CMNE by 107 Hz. Finally, her [ɑ] (621 Hz) is pronounced differently from [ɑ] (780 Hz) in CMNE by 159 Hz. Table 2 highlights the similarities and differences, with the different vowels being in bold.

Words		**fleece**	**kit**	**face**	**dress**	**trap**	**lot**	**cloth**	**goat**	**foot**	**goose**	**strut**	**letter**
Vowels		[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]	[ɚ]
CMNE	F1	404	485	462	636	821	780	577	526	547	427	674	542
PAIGE	F1	513	546	642	658	714	621	629	558	558	482	645	519
DIFF	F1	**109**	61	**180**	22	**107**	**159**	52	32	11	55	29	23

Table 3: Masking on F1 Bandwidth

The vowels that Author 2 produces differently can be classified by place of articulation. We have the front vowels [i] and [e] and the low vowels [æ] and [ɑ]. When producing the first two vowels, Author 2 opens her mouth more widely, so much so that her [i] and [e] are substantially lowered in comparison with similar vowels in CMNE. This pronunciation leads to intelligibility problems because her lowered [i] (513 Hz) masks [ɪ] in CMNE (485 Hz). Since the acoustic distance between these two different phonemes is only 28 Hz, confusion is to be expected. With a relative functional load (RFL) of 95%, this can cause serious misunderstanding if the speech context is not redundant enough (Koffi 2021a:49). In a similar fashion, her [ɪ] (485 Hz) can mask her [e] (462 Hz) since only 23 Hz separates them. Since their RFL is 80%, unintelligibility is to be expected. When we compare her [e] (642 Hz) with [ɛ] (636 Hz) in CMNE, we see that only 6 Hz separates them. However, the intelligibility problem here is not as acute because the RFL between these two vowels is only 53%. All in all, we see that her [ɪ] can create a nexus of confusion between [i] and [e].

In producing the vowels [ɑ] and [æ], Author 2 does not open her mouth wide enough. So, instead of producing real low vowels, she tends to produce mid-low vowels. Her [ɑ] (621 Hz) and her [ɔ] (629 Hz) mask each other with only 8 Hz difference between them. However, no intelligibility problems arise here because these two vowels have merged in CMNE (Koffi 2013:12-3). All things considered, Author 2 has only one true low vowel, which is [æ] (714 Hz). Even so, her low vowel [æ] is not as low as how her CMNE counterparts produce it (821 Hz). There is a substantial difference of 107 Hz between her [æ] and the one that speakers from her dialect area produce.

4.3 Masking on the F2 Frequency Bandwidth

It is generally accepted that F2 correlates with accentedness. Kent and Read (2002:111) explain it as follows, "Possibly, the F2 frequency is more sensitive to dialectal and idiolectal variation than is F3." If we compare the F2 of two or more speakers from the same dialect area, we expect the acoustic distance between their respective vowels to be ≤ 200 Hz. Implicit in this claim is that, if two or more people are from the same dialect area, they will produce their vowels similarly. Consequently, more masking is expected. If masking does not occur, it means that they do not sound like people from that area. In American English, vowels are the main carriers of accentedness. Let's examine Author 2's measurements to see how she sounds relative to CMNE speakers.

Words		**fleece**	**kit**	**face**	**dress**	**trap**	**lot**	**cloth**	**goat**	**foot**	**goose**	**strut**	**letter**
Vowels		[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]	[ɚ]
CMNE	F2	2434	1948	2374	1661	1731	1382	1325	1269	1459	1557	1577	1615
PAIGE	F2	2103	1922	1984	1344	1406	1137	1464	1294	1494	1349	1454	1740
DIFF	F2	**331**	26	**390**	**317**	**325**	**245**	139	25	35	**208**	123	125

Table 4: Masking on F2 Bandwidth

On the F2 frequency bandwidth, we see that 6 out 12 vowels (50%) are different from the vowels produced by CMNE speakers. The vowels in question are [i, e, ɛ, æ, a, u]. This provides additional insights into what Author 2 said about her accent, that is, "I have been told by peers before that my speech does not sound like I have a Minnesotan accent, or even any accent." Since 50% of her vowels are different from those of CMNE speakers, people are unsure about her dialect. People from CMNE who do not know that Author 2 was born and has grown up in Central Minnesota cannot relate to her accent because she does not sound like them. Since they cannot determine her accent vis-à-vis regional dialects in the USA, they conclude that she has "no accent." This is a euphemism for "We cannot put a finger on where you are from. You don't sound like anybody we know."

4.4 Acoustic Vowel Space

The measurements extracted from F1 and F2 frequency bandwidths allow us to visualize what happens inside the mouth of Author 2 when she produces her vowels. Ladefoged and Johnson (2015:234) underscore the importance of creating acoustic vowel spaces such as in Figure 1 to gain more insights when one is comparing dialects or languages.

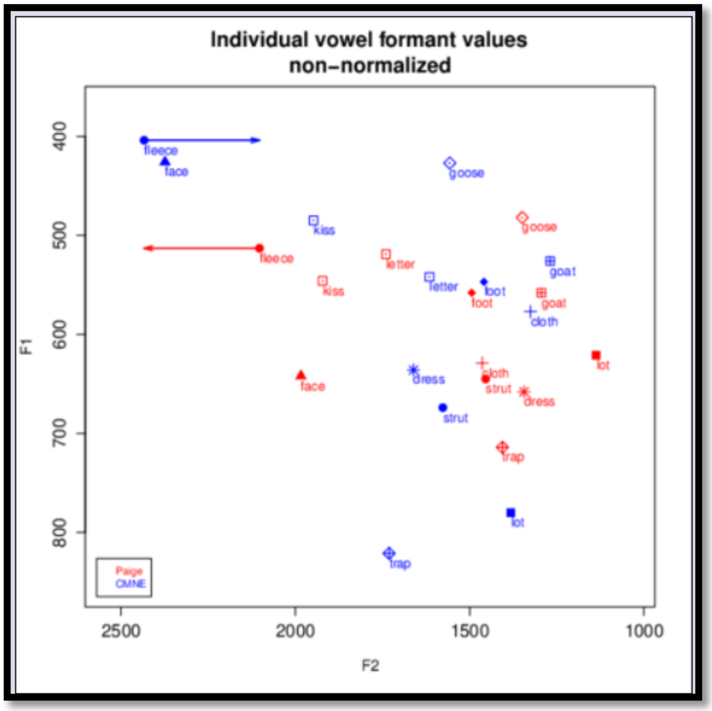

Figure 1: Comparative Acoustic Vowel Space

Author 2's vowels are in red ink (online), while the vowels produced by CMNE speakers are in blue ink (online). The most striking difference between Author 2 and CMNE speakers is that her vowels are produced for the most part in the central area or in the back of her mouth. The phonological term for describing this articulation pattern is **centralization**. The vowels that she should typically produce as front vowels have moved to the center of her acoustic vowel space. For this reason, she has no true front vowels to speak of. The topmost part of her acoustic vowel space is sparsely populated, which means that she hardly produces any high vowels. Similarly, when we look at the bottommost part of her acoustic vowel space, we see that she does not produce any real low vowels. These observations confirm that her mouth is partly open most of the time, and her tongue hardly moves forward toward her front teeth. This can be explained by her postlingual hearing loss, which is hearing loss acquired after the development of speech and language. Kishon-Rabin et al. (1999) have identified speech-errors common in postlingually deafened individuals, one of them being "decreased vowel space due to centralization of the first two formants." Author 2 did not receive any speech therapy help for her stuttering and/or hearing loss while growing up. If she had received pronunciation help, her therapists would have used an acoustic vowel space such as this one as a diagnostic tool to identify the problematic vowels in her speech. They would have taught her different mouth aperture exercises. They would have also taught her to thrust her tongue forward toward her front teeth when producing the vowels [i], [e], [ɛ], and [æ].

5.0 Other Speech Production Issues

The measurements in Table 5 highlight additional issues with Author 2's vowels. These issues are rooted in the strategies that she has developed over the years to cope with her speech impediment (see sections 2.1 and 2.2). The two issues that we will consider briefly are illustrated by the duration and intensity measurements in Table 5.

Words	**fleece**	**kit**	**face**	**dress**	**trap**	**lot**	**cloth**	**goat**	**foot**	**goose**	**strut**	**letter**
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]	[ɚ]
DUR	156	97	127	82	160	187	116	124	108	177	138	112
PAIGE	260	162	311	230	231	291	308	203	293	244	167	87
DIFF	**104**	**65**	**184**	**148**	**71**	**104**	**192**	**79**	**185**	**67**	**29**	**25**
Intensity	55	55	54	58	57	57	54	55	57	55	56	61
PAIGE	63	65	64	68	65	66	65	66	66	66	69	67
DIFF	**8**	**10**	**10**	**10**	**8**	**9**	**11**	**11**	**9**	**11**	**13**	**6**

Table 5: Duration and Intensity Measurements

5.1 Vowel Lengthening

Due to her stutter, the duration of Author 2's vowels is noticeably different. She explains it as follows, "When I stutter, I have repetitions, prolongations, and blocks, which cause me to repeat, lengthen the duration of, and get stuck on phonemes/groups of phonemes." This is seen clearly by how the duration of her vowels differs from those produced by CMNE speakers. The way the naked ear perceives durational differences is stated in the JND below.

JND in the Duration Domain

Of two speech signals **A** and **B** lasting <200 msec, **A** is perceived as longer than **B** if and only if the temporal distance between them is ≥ 10 msec (Koffi 2021b:7).

All the vowels in Author 2's pronunciation occurred in running speech. The duration averages reported for CMNE speakers also occurred in running speech. A vowel-by-vowel comparison shows that Author 2 produced every single vowel longer than her CMNE counterparts. Collectively, CMNE vowels lasted 132 msec, whereas Author 2's vowels lasted 232 msec. In other words, her vowels are on average 100 msec longer than those produced by CMNE speakers. With regard to the JND, her vowels last 10 times longer than expected. Her interlocutors would perceive her speech as too slow and too deliberate.

5.2 Vowel Amplification

To fully understand what is meant by **"amplification,"** we must refer to Author 2's statement about her "outer voice," "… because of the nature of my hearing loss, I cannot hear the outer voice without my cochlear implants on and must rely on the "inner voice" to determine the intelligibility and social appropriateness of my voice/speech." In order to fully grasp the amplification issue, we must refer to the JND of intensity. It explains how the naked ear perceives intensity, i.e., loudness.

JND in the Intensity Domain

Speech segment **A** is perceived as being louder than speech segment **B** if and only if the intensity difference between them is ≥ 3 dB (Koffi 2020:12).

A vowel-by-vowel comparison shows that Author 2 produced every vowel louder than her CMNE counterparts. She produced the 12 vowels with an overall intensity level of 65 dB compared with 56 dB produced by her CMNE counterparts. The difference of 9 dB means that she almost produced her vowels twice as loud as CMNE speakers. This is particularly true for the vowels [ɪ, e, ɛ, ɔ, o, u, ʌ] which are 10 or 11 dB higher than their counterparts in CMNE. If she does not have her cochlear implants on when talking to people, they may wonder why she is shouting at them even though this may not be her intention.

6.0 Summary

The measurements indicate that Author 2's vowels differ from those produced by her CMNE counterparts in spectral characteristics, in duration, and in intensity. F1 shows that [i] masks [ɪ], and [e] masks [ɛ]. F2 explains why those who have heard her speak cannot pinpoint the source of her accent. Her speech is unlike that of CMNE speakers because half of her vowels are produced differently. Lack of accentedness is a by-product of her impediment, not as a result of a conscious and deliberate effort on her part to be different from everyone else in her dialect area. The coping strategies that she has learned to manage her stuttering have resulted in a deliberate speech pattern that can be perceived at times as too slow. If her cochlear implants are not on, since she cannot monitor her "outer voice," her interlocutors might assume wrongly that she is yelling at them, which is not her intention. The data that Author 2 generated in the course of the semester is massive. It includes stops, fricatives, affricates, liquids, glides, syllable onsets, coda clusters, lexical stress, and intonation patterns. We have chosen to report only on vowels because of they play a greater role in intelligibility and accentedness.

ABOUT THE AUTHORS

Ettien Koffi, Ph.D. linguistics (Indiana University, Bloomington, IN) teaches at Saint Cloud State University, MN. He is the author of five books and author/co-author of several dozen articles on acoustic phonetics, phonology, language planning and policy, emergent orthographies, syntax, and translation. His acoustic phonetic research is synergetic, encompassing L2 acoustic phonetics of English (Speech Intelligibility from the perspective of the Critical Band Theory), sociophonetics of Central Minnesota English, general acoustic phonetics of Anyi (a West African language), acoustic phonetic feature extraction for application in Automatic Speech Recognition (ASR), Text-to-Speech (TTS), voice biometrics for speaker verification, and infant cry bioacoustics. Since 2012, his high impact acoustic phonetic publications have been downloaded **54,717** times (**37,140** as per Digital Commons analytics), **17,577** (as per Researchgate.net analytics), and several thousand downloads from Academia.edu, as of **February 2023**. He can be reached at enkoffi@stcloudstate.edu.

Paige Gerlach (she/her) is an undergraduate student at Saint Cloud State University, majoring in Communication Science and Disorders (CSD), with a minor in English as a Second Language (ESL). As part of her areas of study, she has completed several courses related to the human speech mechanism, speech and language production, speech/language/hearing disorders and treatment, teaching English to non-native speakers, linguistics, and phonetics. She developed a stutter at a young age, though never received speech-therapy, which continues to this day. She has a progressive bilateral sensorineural hearing loss, resulting in deafness in both ears. She received bilateral hearing aids at 15 years old and cochlear implants in both her right and left ears at 17 and 19 years old, respectively. She can be reached at paigeegerlach@gmail.com or pegerlach@go.stcloudstate.edu.

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