Koffi, E. (2014). An instrumental account of the intelligibility of [ʌ] in seven varieties of L2
    Englishes. In J. Levis & S. McCrocklin (Eds). *Proceedings of the 5th Pronunciation in
    Second Language Learning and Teaching Conference* (pp. 11-21). Ames, IA: Iowa State
    University.

An Instrumental Account of the Intelligibility of [ʌ]
in Seven Varieties of L2 Englishes

Ettien Koffi, St. Cloud State University

Munro, Flege, and MacKay (1996, p. 328) and Munro and Derwing (2008, p. 493) report the results of perception studies in which they found that [ʌ] was one of the least well perceived vowels by General American English (GAE) hearers of L2 Englishes. Exploratory acoustic phonetic studies conducted on seven varieties of L2 Englishes support their findings in part. Indeed, the vowel [ʌ] in these seven varieties of L2 Englishes overlaps acoustically with or encroaches on [æ] or [ɑ]. As a result, GAE hearers may have a hard time perceiving [ʌ] accurately. However, confusion data from Peterson and Barney (1952) and Hillenbrand et al (1995) also indicate that [ʌ] is among the least well perceived vowels of GAE. It is perceived accurately 92.2% of the time in Peterson and Barney, and 90.8% of the time in Hillenbrand et al. The infelicitous perceptions of [ʌ] may be due to the realignment of vowels in the acoustic vowel space that is going on presently in GAE. As a result, some other vowels are overlapping with the acoustic vowel space of [ʌ]. Small (2005, p. 79) notes, for instance, that many participants in his acoustic phonetic studies confuse [ʊ] and [ʌ]. I contend in this paper that the poor intelligibility of [ʌ] may have as much to do with the dialect(s) of the intelligibility judges as with the acoustic production of the L2 talkers. Furthermore, I contend that researchers can gain greater insights into the intelligibility of vowels if L2 production data is assessed instrumentally and used in tandem with confusion data that is already available for GAE and other accented Englishes. Doing so can help us determine the real sources of the intelligibility problems with L2-accented production of [ʌ].

Classificatory and Perceptual Difficulties

It is practically impossible to classify the vowel [ʌ] by itself without having to make a reference to another vowel. Therein lie the production and perception difficulties that will be addressed in this paper. Fromkin, Rodman and Hyams (2014, p. 206) define [ʌ] as follows: "The vowel [ʌ] in the word *luck* [lʌk] is a central vowel pronounced with the tongue low in the mouth though not as low as with [ɑ]." In this case, [ʌ] is contrasted with [ɑ]. Ladefoged (2006, pp. 90, 219) also defines [ʌ] by contrasting it with [ɔ] in one case, and [ɜ] in another case. In the "official" IPA chart, [ʌ] is classified as a back vowel where it occupies the same position with [ɔ]. These classificatory difficulties are symptomatic of the perception hurdles that GAE hearers face when they are asked to render intelligibility judgments on the segment [ʌ] produced by non-native speakers.

More often than not, they mistake non-native [ʌ] for [ɑ/ɔ] or for [æ]. In this paper, acoustic measurements of [ʌ] are provided in three dialects of American English and seven varieties of L2 Englishes to explain why these confusions exist.

Data Collection and Background Information

The data for the acoustic measurements of [ʌ] in L2 Englishes come from Arabic, Mandarin, Hispanic, Japanese, Korean, Slavic, and Somali speakers of English who were enrolled in my advanced undergraduate phonetics and my graduate phonology courses. The data from the three dialects of American English are from Peterson and Barney's (1952) classic study of GAE vowels, Hillenbrand et al.'s (1995) replication of their study for Midwestern English, and Koffi's (2013) replication of these two studies for the study of vowels in Central Minnesota. The non-native speaking participants in this study were asked to produce the same eleven words that native speakers of American English produced in the three studies mentioned above. The words are: *hid, heed, hayed, head, had, who'd, hood, hoed, hawed, hod,* and *hud*. Each word was produced three times. The words were recorded on laptop computers with built in microphones. Approval was obtained from the Institutional Review Board prior to the beginning of the study. The number of participants varies greatly, from three in the case of Slavic speakers to more than twenty in the case of Central Minnesota speakers.

The vowel [ʌ] is worth singling out for study for three main reasons. First, it is a high frequency vowel in English. According to Faircloth and Faircloth (1973, p. 18), it is the eighth most frequent vowel in English. It also carries a moderate relative functional load. According to Catford (1987, p. 89), the relative functional load of [ʌ] vs. [æ] is 68%, the one for [ʌ] vs. [ɑ/ɔ] is 65%, and [ʌ] vs. [ʊ] is 9%. The second reason for studying [ʌ] has to do with the fact that it is more prone to regional variations than any other GAE vowels. For this reason, I contend in this paper that some of the poor intelligibility scores given by intelligibility judges has as much to do with the judges' own inability to perceive [ʌ] accurately as with the inaccurate production by non-native speakers. Finally, [ʌ] is worth studying because its F1 formant values often overlap with those of [æ] or [ɑ/ɔ] in L2 Englishes.

The paper is organized as follows. Section 3.0 provides the necessary background for the instrumental assessment of intelligibility. In section 4.0, I provide acoustic data to support my contention that GAE talkers and hearers do not perceive [ʌ] completely accurately. It is customary in the acoustic phonetic study of vowels to discriminate between adult females and adult males because of the significant differences that are found in the laryngeal structures of the two genders. For this reason, the intelligibility of [ʌ] in L2 varieties of English is divided according to the gender of the participants. Section 5.0 focuses on the acoustic vowel space of the female participants, while section 6.0 concentrates of the acoustic vowel space of their male counterparts. For each gender group, cursory explanations are offered to assess the intelligibility of [ʌ] instrumentally. More in-depth discussions are devoted to how Mandarin females and Spanish-speaking males produce [ʌ]. Mandarin and Spanish-speaking [ʌ] are singled out for extra scrutiny

because there are already published studies on vowel confusion in these two varieties of L2 English. Focusing on them offers the opportunity to test the validity of an instrumental assessment of vowel intelligibility.

The Foundational Principles of Instrumental Assessment of Intelligibility

The overwhelming majority of the claims about the intelligibility of L2 vowels are based on how native speaker judges aurally perceive the vowels produced by non-native speakers. The present study departs from this long-held tradition and seeks to assess the intelligibility of L2 vowels instrumentally. In this approach, intelligibility is based purely on the acoustic cues produced by non-native speakers. At the core of this analysis is the Perceptual Distance Hypothesis (Johnson 2012, p. 119). It is formulated here as follows:

<div align="center">

Perceptual Distance Hypothesis (PDH)
Segments that are acoustically closer tend to be confused with each other.

</div>

Following Labov et al. (2013, p. 43), I propose that if the acoustic distance between two front vowels or two back vowels is 60 Hz or less on the F1scale, intelligibility can be compromised. The calculation of the acoustic distance between vowels is based solely on the F1 formant frequency because, according to Ladefoged (2006, p. 188), it contains by itself 80% of the acoustic energy of the vowels. Generally though, since there are varying degrees of intelligibility (Byrd and Mintz 2010, p. 72), the smaller the acoustic distance between vowels, the greater the potential for confusion, i.e., unintelligibility.

The Vowel [ʌ] in Three Dialects of GAE

Before GAE judges can render reliable judgments on the intelligibility of [ʌ] in L2 English, we must make sure that they can perceive it accurately when it is produced by other GAE talkers. Available confusion data shows that [ʌ] is the second worst perceived vowel in English. According to Peterson and Barney (1952, p. 183, Table I), [ʌ] is confused with [ɑ/ɔ] 5% of the time. Overall, GAE hearers perceive it accurately 92.2% of the time. The percentage of accurate perception drops to 90.8% of the time in the Midwest (Hillenbrand et al. 1995, p. 3108, Table VI) because [ʌ] is confused with [ɑ/ɔ] 5.5% of the time. It is also confused with [ʊ] 3.2% of the time.1 In fact, Table 1 shows that there has been a gradual but steady reduction of the acoustic distance between [ʌ] and [ɑ/ɔ] on the one hand, and [ʌ] and [ʊ] on the other, in three dialects of American English.

---

1 **The focus here is on female speech because I have not yet dealt with the acoustic vowel space of Central Minnesota male English. In Peterson and Barney, [ʌ] is confused with [æ] 0.07% of the time. In the Midwest, [ʌ] is not confused at all with [æ]. Other rates of confusion are so infinitesimal that they do not warrant any further comments.**

Table 1
Comparative Formant Values in Three Dialects of Female US English

Words		hod	hud	hood	Distance	Distance
Vowels		[ɑ]	[ʌ]	[ʊ]	[ʌ] vs. [ɑ]	[ʌ] vs. [ʊ]
Peterson and Barney	F1	850	760	470	90	290
	F2	1220	1400	1160	180	240
Hillenbrand et al.	F1	936	753	519	183	234
	F2	1551	1426	1225	125	201
Central Minnesota	F1	855	743	626	112	117
	F2	1462	1643	1519	181	124

The acoustic distance between [ʌ] and [ʊ] deserves special attention because the two segments are being increasingly confused by American speakers. The acoustic distance between [ʌ] and [ʊ] is 290 Hz in Peterson and Barney in GAE female English (760 – 470 Hz). It drops to 234 Hz in Hillenbrand et al. (753-519 Hz). Among Central Minnesota female talkers, the acoustic distance drops precipitously to 117 Hz (743 – 626 Hz). Central Minnesota is far from being the only region of the USA where the acoustic distance between [ʌ] and [ʊ] has dropped so drastically. Small's (2005, p. 79) claim that "college students in the Midwest confuse [ʌ] and [ʊ]" is further evidence that this phenomenon may be far more widespread than has been acknowledged in the literature. Prator and Robinett (1985, pp. 138-140) also write about the confusion of [ʌ] and [ʊ]. I contend that the reduced acoustic distance between [ʌ] and [ʊ], as evidenced by the data on Central Minnesota English predisposes many speakers to not perceive [ʌ] and [ʊ] accurately. Data from Boberg (2008, pp. 137-139) and Walden (2012, pp. 188-189) on Canadian English indicate that speakers from the British Columbia area from where many of Munro and Derwing's (2008) intelligibility judges were recruited are predisposed at not perceiving the difference between [ʌ] (760 Hz) and [ʊ] (619 Hz) accurately because the acoustic distance between them in their dialect of Canadian English is only 141 Hz. Consequently, the intelligibility judgments that they render on L2 [ʌ] are more likely to be inaccurate. 2

The Intelligibility of [ʌ] in L2 Female Englishes

One main difference between L1 and L2 Englishes as far as confusion is concerned is that native speakers hardly confuse [ʌ] with [æ], while such confusions are commonplace in non-native varieties of English. Articulatorily, non-natives speakers pronounce [ʌ] in ways that are not confusable with [ʊ], unlike some native speakers of English. These two differences explain why [ʊ] is not mentioned in this section and the next. They also justify the inclusion of [æ] in these two sections, but not in the previous one. The native

---

2 During this research project, acquaintances of mine recounted many anecdotal stories in which they have misperceived words such as <hut> vs. <hot>, <mums> vs. <moms>, <buck> vs. <bock>, <cut> vs. <cot>, <gut> vs. <got>.

languages of the female talkers whose [ʌ] is studied here are Japanese, Korean, Mandarin, Slavic, and Spanish, as shown in Table 2.

Table 2
Comparative Formant Values in L2 Female Englishes

Words		had	hud	hod
Vowels		[æ]	[ʌ]	[ɑ]
Japanese	F1	844	894	772
	F2	1685	1574	1525
Korean	F1	717	634	817
	F2	1589	1136	1487
Mandarin	F1	900	938	853
	F2	1968	1664	1397
Slavic	F1	821	882	843
	F2	1937	1683	1443
Hispanic	F1	847	719	746
	F2	1773	1493	1446

The comparative acoustic vowel space in Figure 1 below is based on the information contained in Table 2.
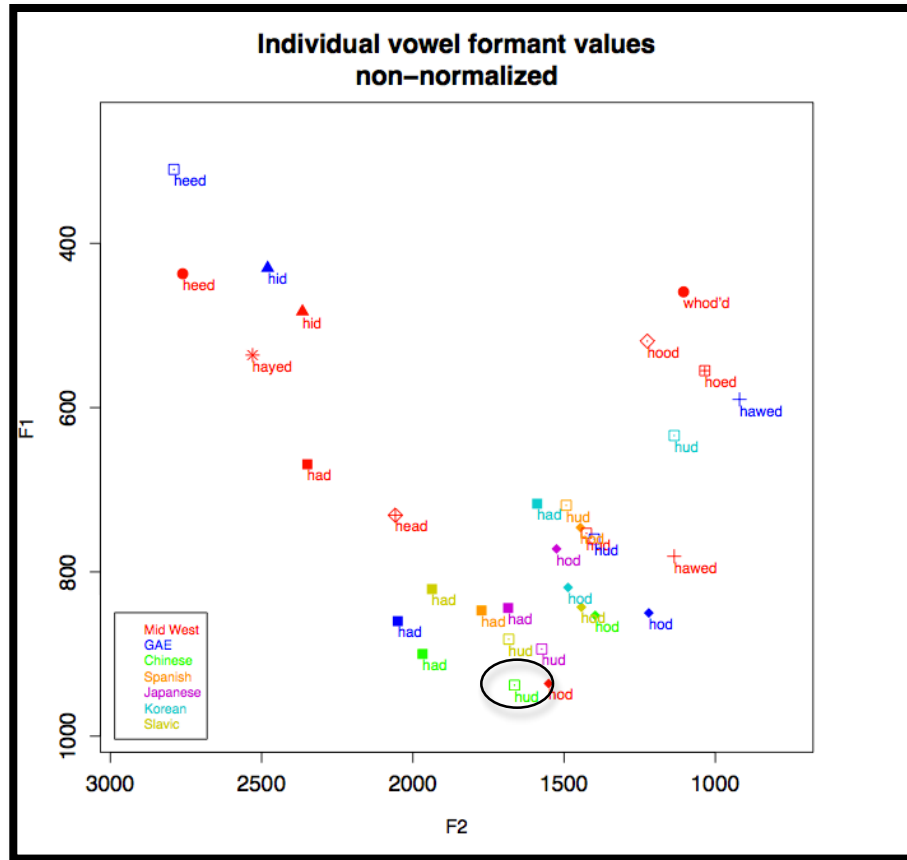
Figure 1. Comparative Acoustic Vowel Space of L2 Female Englishes

A look at Figure 1 shows that the Korean [ʌ] (634 Hz) can be very easily confused with [ɔ] (590 Hz) in GAE because the distance between them is 44 Hz. The Japanese [ʌ] (894 Hz) can be confused with [ɑ] (936 Hz) in GEA because they are separated by 42 Hz. The same is true for the Slavic [ʌ] (882 Hz) that is distant from [ɑ] in GEA by 39 Hz. The way in which Spanish-speakers produce [ʌ] (719 Hz) is barely distinguishable from the way they produce their [ɑ] (746 Hz) because only 27 Hz separate them. As is well known, human beings cannot perceive frequencies differences of less than 20 Hz (Ferrand 2007, p. 34). For this reason, it is doubtful that GAE hearers can unambiguously distinguish between [ʌ] and [ɑ] in Spanish-accented English (see section 6.0 for additional evidence). Since the acoustic distances between [ʌ] and [ɑ] or [ʌ] and [ɔ] in these L2 Englishes are less than 60 Hz, varying degrees of confusion (unintelligibility) are to be expected. We now leave these L2 varieties to concentrate on Mandarin-accented English because this L2 variety has benefited from three important vowel perception studies.

Jia, Strange, Wu, Collado, and Guan (2006) conducted a vowel intelligibility study involving 222 Mandarin speakers, and their findings provide empirical support for the Perceptual Distance Hypothesis discussed in 3.0. The researchers divided Mandarin talkers into three groups: 91 "Monolinguals," that is, people with little or no English, 77 "Recent Arrivals," namely people who had lived in the US less than two years, and 54

"Past Arrivals," those who had been in the USA between 3 and 5 years. They report the following intelligibility rating of their production of [ʌ]. This segment was perceived accurately at rates of 54.3% in the production of Monolinguals, 44.7% in the speech of by Recent Arrivals, and 48.8% in the samples provided by Past Arrivals. The results of this study suggest that length of residency (LOR) does not have any positive effect on the production of [ʌ]. My acoustic measurements of [ʌ] produced by seven TESL graduate students whose native language is Mandarin bear this out. The average F1 formant of [ʌ] in Mandarin-accented English is 938 Hz. According to Hillenbrand et al. (1995), this anglicized [ʌ] encroaches on the acoustic vowel space of [ɑ] (936 Hz) in the dialect of GAE spoken in the Midwest. The acoustic difference of 2 Hz between the two is sub-sonic (Ferrand 2007, p. 34), that is, under the threshold of human aural perception. In other words, when Mandarin talkers produce [ʌ], Midwestern hearers perceive it as [ɑ] instead. Unlike Munro and Derwing (2008, p. 488) who found that Mandarin speakers improved their [ʌ] from periods T1/T2 to periods T5/T6, Jia et al.'s (2006) findings suggest that LOR does not improve the production of [ʌ]. In fact, the Mandarin talkers who provided data for this study had had on average 12 years of formal instruction in English as a foreign language in China prior to coming to the US. By the time their speech samples were collected, they had been living and studying in the US for two years or more. The acoustic data also seem to indicate that formal linguistics training does not seem to have any appreciable positive impact on their production of [ʌ]. My instrumental acoustic findings are further bolstered by Lai's (2010, p. 171) confusion study of Mandarin-accented English vowels. It was found that [ʌ] was perceived accurately only 22% of the time, while 78% of the time, GAE hearers confused [ʌ] with [ɑ]. This is not at all surprising, since the acoustic distance between Mandarin-accented [ʌ] and Midwest [ɑ] is only 2 Hz.

The Intelligibility of [ʌ] in L2 Male English

Let's now turn our attention to the ways in which the male talkers in the study produced [ʌ].

Table 3
Comparative Formant Values in L2 Male Englishes

Words		had	hud	hod
Vowels		[æ]	[ʌ]	[ɑ]
Arabic	F1	665	611	685
	F2	1504	1243	1154
Japanese	F1	702	596	542
	F2	1694	1385	1150
Korean	F1	640	572	694
	F2	1224	1055	1291
Somali	F1	678	629	609
	F2	1674	1532	1339
Spanish	F1	647	531	593
	F2	1491	1529	1196

Table 4
Comparative Formant Values in Two Dialects of US Male English

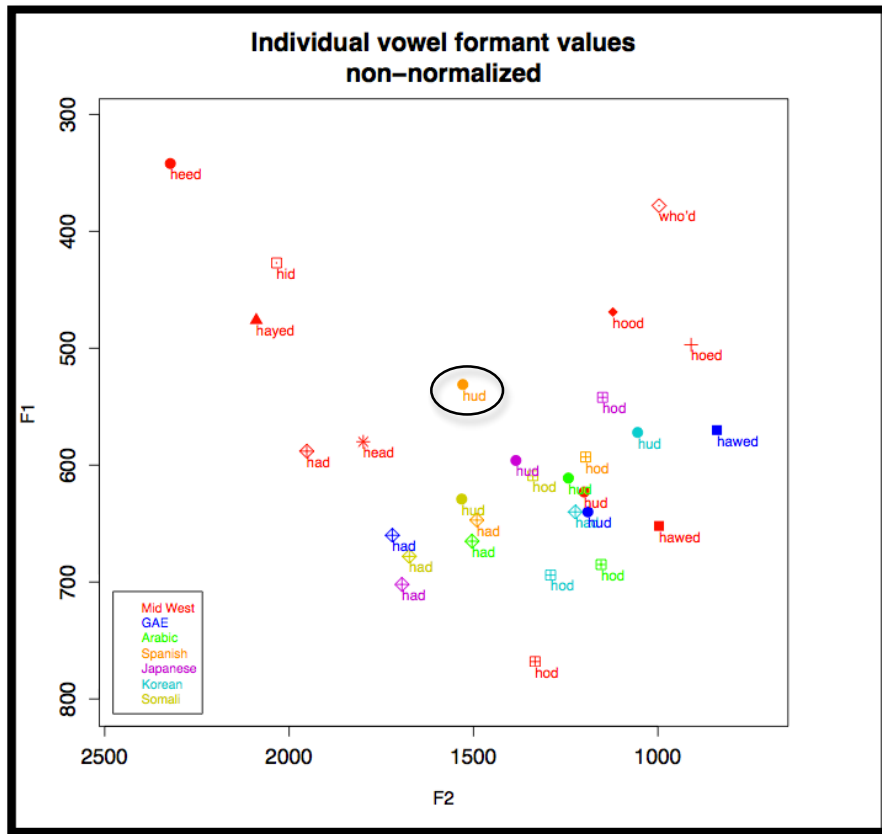| Words		had	hud	hod
Vowels		[æ]	[ʌ]	[ɑ]
Peterson and Barney	F1	660	640	730
	F2	1720	1190	1090
Hillenbrand et al.	F1	588	623	768
	F2	1952	1200	1333

Figure 2. Comparative Acoustic Vowel Space for Males

Suffice it to say for now that Korean and Japanese-accented [ʌ] (572 Hz) may be misperceived by GAE hearers because it encroaches on the acoustic space of their [æ]. The segment [ʌ] produced by Arabic (611 Hz) and Somali (629 Hz) talkers is confusable with [æ] because their anglicized [ʌ] encroaches on the acoustic space of [æ] in GAE. Furthermore, the ways in which talkers produced [ʌ] in most of these varieties of L2 Englishes cause it to overlap acoustically with [æ], except in Japanese and Spanish. It can be concluded that intelligibility issues arise either because [ʌ] encroaches on [æ] in GAE, or because it overlaps with [æ] in accented Englishes, or both. Let's elaborate this further by examining the confusion data concerning [ʌ] in Spanish.

Lecumberri and Iragui (1997, p. 59) conducted a confusion study in which speakers of Received Pronunciation, a "standard" dialect of British English, were asked to rate the intelligibility of the [ʌ] produced by college students in Spain majoring in English. Overall, Spanish-accented [ʌ] was perceived accurately 81.6% of the time. However, the same study found that [ʌ] was confused with [æ] 15.8% of the time, and with [ɑ] 0.9% of the time. These findings lend support to the Perceptual Distance Hypothesis (PDH). Eight male speakers from various Latin American countries produced the [ʌ] circled in Figure 2. We see that their [ʌ] is the only one among the speakers of seven varieties of L2 English that is sufficiently distinct from other GAE vowels so as not to cause confusion. Yet, the acoustic data also shows the Hispanic [ʌ] (531 Hz) is acoustically not very distant from how Midwesterners produce [æ] (588 Hz). The acoustic distance of 57 Hz between these two segments means that confusion is still possible. The Spanish data confirm this by showing that [ʌ] is confused with [æ] 15.9% of the time. Not only does PDH predict accurately that confusion is likely between Hispanic-accented [ʌ] and [æ], but it also predicts accurately that GAE hearers are less likely to confuse Hispanic-accented [ʌ] with the way they produce [ɑ] (593 Hz). It is, therefore, not surprising that Lecumberri and Iragui found that [ʌ] was confused with [ɑ] only 0.9%.

Summary

This study complements the growing body of evidence that has been accumulating for more than a decade regarding the relatively poor intelligibility scores that GAE hearers give to L2 English pronunciations of [ʌ]. However, unlike the previous intelligibility studies that are based on impressionistic judgments rendered by native speaker judges, the present study has relied on an instrumental acoustic methodology to account for why non-native [ʌ] is often poorly perceived. In so doing, three contributing factors have been uncovered. The first has something to do with the dialect of American English that the intelligibility rater speaks. Data from Peterson and Barney (1952) and Hillenbrand et al. (1995) show that Midwest hearers perceive [ʌ] less accurately when they listen to GAE talkers from other regions of the USA. Acoustic phonetic data by Koffi (2013) find that Central Minnesotans fare even worse in their intelligibility of [ʌ] because, not only do they occasionally confuse it with [ɑ/ɔ] like other GAE speakers, but they are also increasingly confusing [ʌ] with [ʊ]. The second factor that contributes to the poor intelligibility of [ʌ] stems from how non-native speakers pronounce it. More often than not, they do not discriminate sufficiently in how they produce [ʌ], [æ], and [ɑ]. As a result, these segments overlap with each other in acoustic vowel space. Last but not least, L2 accented [ʌ] is often not intelligible because it encroaches on the acoustic vowel space of [æ] or [ɑ/ɔ] in GAE. Acoustic phonetic overlapping and/or encroachment interferes with intelligibility because in either case, GAE hearers cannot disentangle [ʌ] from [æ] or [ɑ] auditorily. Given the moderate to high relative functional load of [ʌ] and [æ] on the one hand, and [ʌ] and [ɑ] on the other, frequent instances of unintelligibility are expected to arise when non-native speakers produce monosyllabic lexical minimal pairs such as <cup>, <cap>, and <cop> , or <but>, <bat> and <bought>.

ABOUT THE AUTHOR

Ettien Koffi is Professor of Linguistics. He teaches the linguistic courses in the TESL/Applied Linguistics M.A. program in the English Department at St. Cloud State University, MN. He has written three linguistic books and is the author of many peer-reviewed articles on various topics in linguistics. His primary area of specialization is at the interface between acoustic phonetics and phonology. He also has extensive experience in emergent orthographies and in the acoustic phonetic and phonological description of dialect variation. He can be reached via email at: enkoffi@stcloudstate.edu.

REFERENCES

Catford, J. C. (1987). Phonetics and the teaching of pronunciation. In J. Morley (Ed.), *Current perspectives on pronunciation: Practices anchored in theory*. Washington, D.C.: Teachers of English to Speakers of Other Languages.

Boberg, C. (2008). Regional phonetic differentiation in standard Canadian English. *Journal of English Linguistics*, 36 (2), 129-154.

Byrd, D., & Toben, M. (2010). *Discovering speech, words, and mind*. Malden, MA: Wiley-Blackwell.

Faircloth, S., & Faircloth, M. (1973). *Phonetic science: A program of instruction*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Fromkin, V., Rodman, R., & Hyams, N. (2014). *An introduction to language, 10th ed.*, New York: Cengage Learning.

Ferrand, C. (2007). *Speech science: An integrated approach to theory and clinical practice, 2nd Ed*. New York: Pearson Allyn and Bacon.

Hillenbrand, J., Getty, L.A, Clark, M. J., & Wheeler, K. (1995). Acoustic characteristics of American English vowels. *The Journal of the Acoustical Society of America*, *97* (5), 3099-3111.

Jia, G., Strange W., Wu Y., Collado, J., & Guan Q. 2006. Perception and production of English vowels by Mandarin speakers: Age-related differences vary with amount of L2 exposure. *The Journal of the Acoustical Society of America*, *119* (2), 1118-1130.

Johnson, K. (2012). *Acoustic and auditory phonetics, 3rd ed.,* Malden, MA: Wiley-Blackwell.

Koffi, E. (2013). The acoustic vowel space of central Minnesota English: Focus on female vowels. *Linguistic Portfolios*, 2: 2-16.

Labov, W., Rosenfelder, I. & Fruehwald, J. (2013). One hundred years of sound change in Philadelphia: Linear incrementation, reversal, and reanalysis. *Language*, 89 (1), 30-65.

Ladefoged, P. (2006). *A course in phonetics*, 5th edition. New York: Thomson-Wadsworth.

Lai, Y. (2010). English Vowel Discrimination and Assimilation by Chinese-Speaking Learners of English. *Concentric: Studies in Linguistics*, 36 (2), 157-183.

Lecumberri, L. G., & Iragui, J. C. (1997). L2 perception of English vowels: Testing the validity of Kuhl's prototypes. Revista Alicantina de Estudios Ingleses, pp. 55-68.

Munro, M., & Derwing T. (2008). Segmental acquisition in adult ESL learners: A longitudinal study of vowel production. *Language Learning* 58 (3), 479-508.

Munro, M. & Derwing T. (2006). The functional load principle in ESL pronunciation instruction: An exploratory study. *System* 34, 520-531.

Munro, M., Flege, J., & MacKay, I. (1996). The effects of age of second language learning on the production of English vowels. *Applied Psycholinguistics,* 17, 313-334.

Peterson, G., & Barney, L. (1952). Control methods in a study of the vowels. *The Journal of the Acoustical Society of America*, *24* (2), 176-84.

Prator, C., & Robinett, B. (1985). *Manual of American English pronunciation, 4*th *edition.* New York: Harcourt Brace & Company.

Small, L. H. (2005). *Fundamentals of phonetics: A practical guide for students, 2*nd *Edition*. New York: Pearson Education, Inc.

Walden, M. (2012). Phonetic portfolio. *Linguistic Portfolios*, 1, 182-193.