Chapter 12

The acoustic vowel space of Anyi in light of the cardinal vowel system and the Dispersion Focalization Theory

Ettien Koffi
St. Cloud State University

The Cardinal Vowel System (CVS) and the Dispersion Focalization Theory (DFT) make an important assumption about the inventory of vowels in world languages. The claim is that languages organize their vowels in a certain way in the auditory-perceptual space so as to maximize intelligibility. The vowel diagrams of African languages in influential publications such as Welmers (1973: 20–45) explicitly or implicitly reflect this assumption. However, persistent confusions between [ɪ] and [e] among Anyi Morofu speakers have aroused my curiosity and led me to investigate the matter acoustically. The findings reported here show that the vowel space of Anyi Morofu is in a between and betwixt state. The data indicates that this dialect is moving from a nine-vowel system to an eight-vowel system through the merger of [ɪ] and [e]. There are also signs of the impending merger of [ʊ] and [o].

1 Introduction

The Cardinal Vowel System (CVS) and the Dispersion Focalization Theory (DFT) agree on the principle that languages organize their vowel inventories in order to maximize intelligibility. The principle underlying both approaches is known as the Principle of Perceptual Separation (PPS). Ladefoged & Johnson (2015: 238) explain it as follows, "One of the forces acting on languages may be called the principle of sufficient perceptual separation, whereby the sounds of a language are kept acoustically distinct to make it easier for the listener to distinguish one from another." This important principle collides with how Anyi Morofu organizes its vowel inventory. Anyi Morofu is the biggest dialect of the Anyi language spoken in Côte d'Ivoire, West Africa. According to the 2000 census (outdated, but there is no other official census data to go by), this dialect is spoken by more than half of the 755,365 Anyi speakers in Côte d'Ivoire. Anyi belongs to the Akan family of languages. Before presenting the evidence for how Anyi Morofu runs counter to the core principle of CVS and DFT, let's acquaint ourselves briefly with these two phonetic frameworks. The goal here is not to review these two theories extensively, but

Ettien Koffi. The acoustic vowel space of Anyi in light of the cardinal vowel system and the Dispersion Focalization Theory. In Jason Kandybowicz, Travis Major, Harold Torrence & Philip T. Duncan (eds.), *African linguistics on the prairie: Selected papers from the 45th Annual Conference on African Linguistics*, 169–180. Berlin: Language Science Press. DOI:10.5281/zenodo.1251730

rather to use the data they provide to explain the perceptual confusion between [ɪ] and [e] and the signs announcing the upcoming merger of [ʊ] and [o].

1.1 A short history of the cardinal vowel system

On the occasion of Ladefoged's sixtieth birthday, Fromkin (1985) put together a collection of papers from influential phoneticians. In Abercrombie's article (1985:17), he gives us a glimpse of how CVS came about. His account is authoritative because he had a front row seat when Jones was designing his method. He was Jones' student and later became Ladefoged's teacher and mentor. He notes that for Jones, CVS was not a theory, but a technique. He describes this technique as follows:

> This way of teaching phonetics meant intensive training of the proprioceptive, i.e., the tactile and kinesthetic senses concerned with the organs of speech, something that is not valued very highly by many other schools of phonetics. The proprioceptive senses, in the view of phoneticians in the Jones tradition, play an important part in the analysis and description of unfamiliar sounds. The phonetician, having learnt to make a sound of the language he is working on to the complete satisfaction of his native informant, then examines what he himself is doing with his vocal organs, and infers the informant is doing the same.

Jones learned to produce a wide variety of vowels this way. Thomas (2011: 146) provides in Table 1 the formant frequencies of 18 vowels that Jones learned to produce.

For the purposes of this paper, the focus will be on nine vowels, [i, ɨ, e, ɛ, a, ɔ, o, ʉ, u], because Anyi also has nine vowels. According to Maddieson's (1984) UCLA Phonetic Segment Inventory Database (UPSID), 17 out the 266 languages in the database have nine vowels. Languages such as Anyi with a nine-vowel system represent only 6.39% of the total number of languages in UPSID. Furthermore, only seven of the 17 nine-vowel languages have a perfect symmetry of four front vowels and four back vowels and one low central vowel. The vowel system of these seven languages is similar to the one we find in Anyi. Jones' cardinal vowel system did not include [ɪ] and [ʊ] because [-ATR] vowels were not known at the time. Even so, the plotting of his vowels gives us a realistic picture of what a nine-vowel system looks like.[1]

A few cursory remarks need to be made. First and foremost, in the nine-vowel system produced by Jones, we see that the PPS obtains. No two vowels overlap in acoustic space. CVS has had a far-reaching impact on how the vowel inventories of African languages are plotted in Welmers (1973: 20–45), in *Atlas des Langues Kwa de Côte d'Ivoire, Tome 1*, and in countless other publications. Thomas (2011: 145–147) opines that Jones' original intention in proposing CVS was only to "standardize impressionistic transcription to make it more useful for interlanguage comparisons," not to idealize it as the acoustic vowel spaces for all languages. Koffi (2009) and all who have described the Anyi vowel quadrant have used this idealized system. This is the reason why the confusion between [ɪ] and [e] came as a surprise because under the idealized Anyi vowel quadrant, unintelligibility was not expected.

[1] The diagrams were produced using Norm, available at http://lingtools.uoregon.edu/norm/norm1.php.

Table 1: Jones' Vowels

N0	Vowels	F1	F2	F3
1.	[i]	266	2581	3627
2.	[ɨ]	312	2078	2544
3.	[ɯ]	337	1275	2180
4.	[u]	248	490	2512
5.	[y]	289	2231	2747
6.	[ʉ]	285	1487	2066
7.	[e]	376	2213	2652
8.	[ø]	353	1946	2375
9.	[ɤ]	569	1153	2282
10.	[o]	354	724	2348
11.	[ɛ]	588	1910	2328
12.	[œ]	554	1549	2158
13.	[ɶ]	722	1227	2180
14.	[ɒ]	582	769	2150
15.	[ʌ]	542	1145	2273
16.	[ɔ]	522	932	2180
17.	[ɑ]	650	940	2472
18.	[a]	929	1688	2354

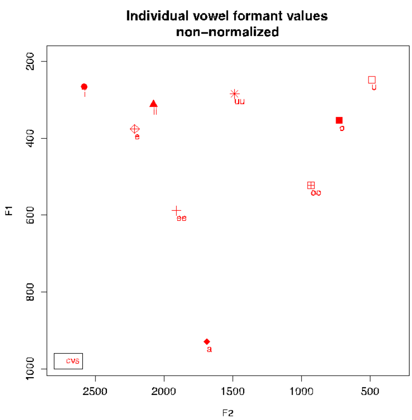

Figure 1: The Norm website does not recognize certain IPA symbols. The following legend is used <ii> = [ɨ], <uu> = [ʉ], <ee> = [ɛ], <oo> = [ɔ] instead.

1.2 A quick overview of the Dispersion Focalization Theory

PPS is also at the core of the Dispersion Focalization Theory (DFT) that Schwartz et al. (1997) put forth. However, Becker-Kristal (2010: 10) contends that "the idea that vowel inventories are structured in a manner that enhances contrast, by maximally dispersing vowels in the auditory-perceptual space, is as old as the intuition that vowel inventories follow universal structural patterns." It is worth stating clearly and unambiguously that the goal pursued in this paper is not to review, critique, or summarize DFT or the Dispersion Theory (DT) from which it sprang. Such an exercise would require us to make a long detour in the histories and developments of these two theories. It is not the theoretical claims of DFT that interest us as much as the impressive amount of formant frequency data provided for 22 "prototypical" vowels, as seen in Table 2. Aspects of this data will be used in Figure 2 to highlight the acoustic vowel space of a prototypical language with a nine-vowel system.

Table 2: Prototypical Vowel Frequencies

N0	Vowels	F1	F2	F3
1.	[i]	277	2208	3079
2.	[ʏ]	277	1937	2232
3.	[ɨ]	277	1520	2310
4.	[ɯ]	277	1218	2500
5.	[u]	277	553	2420
6.	[ɪ]	344	2170	2660
7.	[y]	344	1770	2230
8.	[ʊ]	344	635	2413
9.	[e]	414	2065	2570
10.	[ø]	414	1608	2250
11.	[ə]	414	1516	2500
12.	[ɤ]	414	1248	2500
13.	[o]	414	721	2406
14.	[ɛ]	565	1819	2528
15.	[œ]	565	1520	2500
16.	[ɜ]	565	1462	2500
17.	[ʌ]	565	1258	2500
18.	[ɔ]	565	915	2373
19.	[æ]	648	1712	2490
20.	[ɐ]	648	1405	2500
21.	[ɑ]	735	1278	2500
22.	[a]	800	1228	2500

Nine of the prototypical vowels, [i, ɪ, e, ɛ, a, ɔ, o, ʊ, u], are also found in Anyi. They are plotted in Figure 2 to show how these prototypical vowels are organized in an acoustic space.

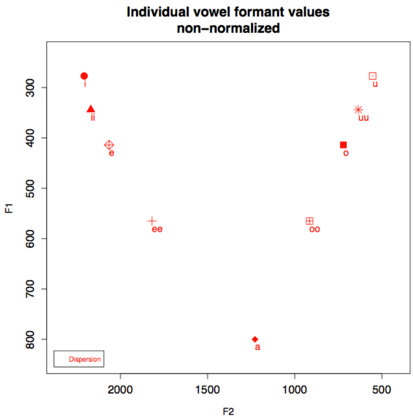

Figure 2: Vowel space of nine prototypical vowels
The Norm website does not recognize certain IPA symbols. The following legend is used for [-ATR] vowels: <ii> = [ɪ], <uu> = [ʊ], <ee> = [ɛ], <oo> = [ɔ].

The plotting shows that the claims of PPS hold here as they did in Figure 1. No vowel encroaches on the space of another vowel. Consequently, intelligibility is maximized. Let's now turn to the Anyi Morofu data and examine its vowel space in light of CVS and DFT.

2 Data collection and participants

Koffi (2009), Quaireau (1987: 27), Retord (1980: 96), to name only the three main researchers on Anyi, have all diagrammed the oral vowels of Anyi as shown in Figure 3:

High Front	i		u	High Back
	ɪ		ʊ	
Mid	e		o	
	ɛ		ɔ	
Low		a		

Figure 3: Anyi Morofu vowel diagram

Anyi also has seven nasal vowels: [ɪ, ĩ, ũ, ʊ, ɛ, ɔ, ã]. The vowels [ɛ] and [ɔ] are deemed unnasalizable in some Akan languages, but not in Morofu. The only vowels that are unnasalizable are [e] and [o] (Koffi 2004). Figure 3 may be an accurate representation of a nine-vowel phonemic system in Anyi Morofu, but it is no longer an accurate representation of its contemporary phonetic vowel system. This became abundantly clear during a literacy seminar in the summer of 2011. During the dictation task, teachers in training confused [ɪ] with [e], and [e] with [ɪ] regardless of who was doing the dictation.[2] Test takers would frequently stop to ask the reader whether he meant [e] or [ɪ] in instances where the contextual cues were not enough to disambiguate the lexical items containing these vowels. For example in a sentence such as, *ɔ’a hɪ nnaán* ‘he trapped an animal’, some test takers wrote *ɔ’a he nnaán* ‘he shared/gave away some of his meat’. The high number of confusion incidences such as these caused me to wonder if a merger was happening between these two vowels in the Morofu dialect spoken in the Bongouanou area. Figure 4 shows this dialect in relation to the other Anyi dialects. As noted earlier, Morofu has more speakers than all the other dialects of Anyi combined.

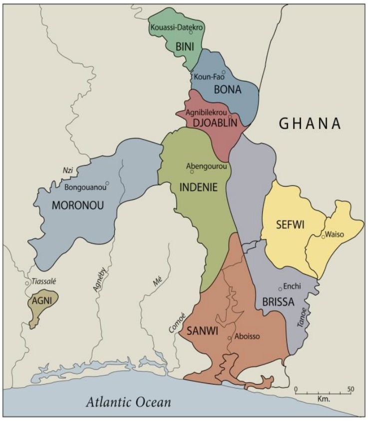

Figure 4: The Anyi dialect area

The matter was investigated further through data collection in the summers of 2012 and 2013 after securing the approval of the Institutional Review Board (IRB) from my university. The same ten male adult literacy teachers were invited again. Female speakers were not intentionally excluded. At that time, there were no female literacy teachers. The situation has now changed and we have three female teachers. The lack of female data does not affect the present analysis negatively because most of the various predictions of DFT and DT are based on male speech (Becker-Kristal, 2010:31). The participants are all bilingual in Anyi and French. They range in age from the 30s to 50s. Each participant produced nine sentences, each containing one of the nine vowels under consideration:

(1) a. <ɔ’a hi> (he/she has refused to eat it)
    b. <ɔ’a hɪ> (he/she has caught it)

[2] Ladefoged (2003: 126,130–131) tells a similar story about Banawa, a language of the Amazonian rain forest in Brazil where there was confusion between [u] and [o] that led to strong disagreements in the orthography of the language.

c. <ɔ'a he> (he/she has shared it)
d. <ɔ'a hɛ> (he/she is late)
e. <ɔ'a hu> (it has boiled)
f. <ɔ'a hʊ> (a nonsense word)
g. <ɔ'a ho> (he/she has dug a whole)
h. <ɔ'a hɔ> (he/she has left)
i. <ɔ'a ha> (he/she has bitten)

Each sentence was repeated three times, for a total of 30 repetitions. The data set consists of 270 items (9 x 3 x 10). The data was collected on an Olympus Digital Voice Recorder WS-710. The participants wore a Panasonic head-mounted, noise cancellation fixed microphone. The recording took place in a quiet room on the premises of the Anyi Literacy and Translation Center (CATA).

2.1 Methodology

The elicitation word in each sentence begins with /h/. These words were chosen intentionally in order to replicate Peterson and Barney's methodology as much as possible. Countless studies of vowels have followed this methodology. Ladefoged (1996: 112) explains the benefits of choosing /h/ in these kinds of acoustic phonetic studies as follows:

> As the positions of the articulators during the sound [h] are similar to those of the surrounding sounds, such as the adjacent vowels, the frequency components in [h] sounds have relative amplitudes similar to those in vowels; but the complex wave has a smaller amplitude and no fundamental frequency, as it is not generated by regular pulses from the vocal cords.

Since [h] exists in Anyi as an allophone of /k/, Peterson and Barney's methodology can be replicated without any problem. The entire duration of the vowel, from the onset to the offset, was measured. It was not deemed necessary for this study to take measurements at various points in the vowel because the environment in which the vowel occurred did not foster co-articulation. Furthermore, the methodology used by Peterson and Barney that is being replicated in this study did not sample vowels at multiple intervals. The onset of each vowel was easily identified because of the frication noise contained in [h]. However, it was more challenging to determine the offset of vowels. In annotating the offset, Thomas (2011: 142) proposes three options:

> … The same problem crops up frequently with vowels before a pause. In these cases, you have another choice to make. One option is to look for a spot where the vocal fold vibrations become more or less unrecognizable or start looking more like staticky patterns of aspiration than the sharper pattern usually evident with vocal fold vibrations. Often, the best way to determine this spot is by moving the cursor to different spots and listening; after a certain point, all you hear is aspiration, and

that point is where you mark the offset. The other option is to mark the offset at the end of the recognizable aspiration, though this point may be quite difficult to define.

For this study, the offset of the vowel was determined by following the second option in Thomas' recommendation, that is, demarcating the offset right before the point at which aspiration is heard. The measurements for one speaker were done manually to ensure that the offsets of vowels are identified accurately. Once the pattern was well established, Ryan's (2005) Grid-maker script for Praat was used to annotate all the vowels produced by the rest of the speakers. Subsequently, Yoon's (2008) Stress-analysis script for Praat was employed to collect all the relevant information displayed in Tables 3 and 4.

Various statistical analyses can be run from the measurements in Tables 3 and 4. However, in this study they are used exclusively for the purpose of generating the acoustic vowel space in Figure 5 and for explaining why Anyi Morofu hearers have a problem distinguishing [ɪ] and [e] aurally.

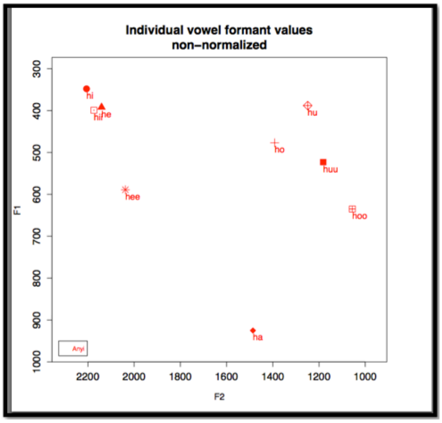

Figure 5: Anyi acoustic vowel space

2.2 The reason for the confusion

Figure 5 shows us visually why Anyi Morofu hearers confuse [ɪ] and [e] aurally. We see that they overlap in perceptual space. The measurements in Table 3 explain why. These two vowels mask each other aurally because [ɪ] (399 Hz) and [e] (392 Hz) are separated by only 7 Hz in the F1 domain. It is a well-known fact that a minimum of 20 Hz is needed for humans to perceive a difference between two sound segments (Ferrand 2007: 34). It is also well known that the lowest frequency at which a sound is intelligible on an eight-octave frequency band is 63 Hz. Auditory frequency measuring devices and many audio applications use this baseline as their reference level (Everest & Pohlmann 2015: 12–16). For acoustic phonetic analyses, this threshold has been rounded down to 60 Hz to make

Table 3: F1 Formant for all participants

F1	[i]	[ɪ]	[e]	[ɛ]	[u]	[ʊ]	[o]	[ɔ]	[a]
Speaker 1	325	368	355	556	423	539	481	624	942
Speaker 2	280	407	408	576	329	595	429	639	885
Speaker 3	307	435	408	623	345	431	414	653	983
Speaker 4	291	344	368	573	384	583	429	677	882
Speaker 5	291	415	361	601	396	510	469	639	980
Speaker 6	304	402	493	662	342	546	556	662	823
Speaker 7	338	378	381	536	473	506	544	634	981
Speaker 8	444	469	449	597	420	491	445	654	940
Speaker 9	255	360	350	584	365	545	544	628	815
Speaker 10	654	421	356	583	405	490	468	635	1028
Mean	348	399	392	589	388	523	477	635	925

Table 4: F2 Formant for all participants

F2	[i]	[ɪ]	[e]	[ɛ]	[u]	[ʊ]	[o]	[ɔ]	[a]
Speaker 1	2265	2167	2192	2068	1383	950	1694	896	1519
Speaker 2	2366	2085	2082	1960	856	859	839	1047	1525
Speaker 3	2298	2462	2350	2397	781	716	773	964	1551
Speaker 4	2202	2231	2211	2043	1216	1151	891	1171	1468
Speaker 5	2402	2534	2455	2192	1105	841	1041	946	1542
Speaker 6	1902	1746	1937	1745	918	1248	1754	1103	1382
Speaker 7	1911	1977	1931	1906	2103?	817	1429	829	1429
Speaker 8	2060	2067	2037	2069	1655	1206	1637	1053	1456
Speaker 9	2351	2208	2234	2026	1371	1804	1985	993	1538
Speaker 10	2304	2269	1985	1982	1960	2228	1885	1561	1455
Mean	2206	2174	2141	2038	1249	1182	1392	1056	1486

calculations simpler (Fry 1979: 68). Labov et al. (2006: 204–221) use it in *Atlas of North American English* (ANAE) to assess dialectal variations. Labov et al. (2013: 43) use it to assess vowel change in Philadelphia. The same 60 Hz threshold is used here to explain the confusion between [ɪ] and [e], and vice versa. Though F2 and F3 formants contribute to the overall perception of vowel quality, the calculations of vowel intelligibility are based on F1 because it alone contains 80% of the acoustic energy in the vowel (Ladefoged & Johnson 2015: 207).

The practical steps used to assess vowel intelligibility are as follows. On the F1 frequency band, if the acoustic distance between two contiguous front vowels or two contiguous back vowels is ≥ 60 Hz, the two vowels are perceived as distinct. However, if their acoustic distance falls between 59 and 21 Hz, intelligibility is compromised. If the acoustic distance between two vowels is ≤ 20 Hz, it means that a merger has taken place or is taking place. The reason for this is because human beings cannot perceive frequencies lower than 20 Hz. This is exactly what is going on with Anyi Morofu. Hearers in general have a hard time distinguishing [ɪ] from [e], and vice versa, because the mean acoustic distance between them is only 7 Hz. There are, however, small inter-speaker variations. The segments [ɪ] and [e] produced by Speakers 5, 6, and 10 are intelligible because the acoustic distances between them are respectively 54 Hz, 91 Hz, and 65 Hz. However, for seven of the speakers [ɪ] and [e] are aurally indistinguishable. For Speakers 1, 2, 7, 8, and 9 the two vowels mask each other because the acoustic distances between them are ≤ 20 Hz, as shown in Table 5:

Table 5: Inter-speaker variation

F1	[ɪ]	[e]	Distance
Speaker 1	368	355	13
Speaker 2	407	408	1
Speaker 3	435	408	27
Speaker 4	344	368	24
Speaker 5	415	361	54
Speaker 6	402	493	91
Speaker 7	378	381	3
Speaker 8	469	449	20
Speaker 9	360	350	10
Speaker 10	421	356	65
Mean	399	392	7
Standard Deviation	37	47	28

The situation in Anyi is similar in this respect to the merger between [ɑ] and [ɔ] that is going on in several dialects of American English. For Central Minnesota English, Koffi (2013: 5) reports that the merger between [ɑ] (855 Hz) and [ɔ] (851 Hz) is complete in the speech of female speakers because the acoustic distance between the two vowels is only 4 Hz.

Cross-linguistically, something is going on between [ɪ] and [e] that deserves further investigation. Ladefoged (1999: 41–42) displays the vowels of a southern California speaker whose [e] has risen above [ɪ]. Koffi's (2014:16–17) acoustic phonetic measurements of Central Minnesota English show that that [e] is higher than [ɪ] in male and female speech. In male speech, [e] (434 Hz) is higher than [ɪ] (542 Hz) by 108 Hz. In female speech, [e] (508 Hz) has risen above [ɪ] (573 Hz) by 65 Hz. In these examples, the raising of [e] above [ɪ] does not result in unintelligibility because the acoustic distance between them is still higher than the 60 Hz threshold. However, this is not so in the case of Anyi Morofu where only a mere 7 Hz separate these vowels. In the terminology that Schwartz et al. (1997) use to describe vowel systems, Anyi is an "atypical" nine-vowel system because it does not conform to the predicted patterns. Becker-Kristal (2010: 169) explains why:

> Across all analyses, inventories with ATR harmony often violate the principles of dispersion, in formant spans, in even vowel spacing and in phonetic adjustments in response to structural change. These deviations are understandable if such inventories are not treated as one large system but as two parallel smaller systems.

More acoustic phonetic data such as the one used to describe the confusion between [ɪ] and [e] is needed from other African languages with [±ATR] vowel systems to see if Anyi Morofu is really atypical or if this phenomenon is widespread. In the case of Anyi, it is the vowels [ɪ] and [e]. In other languages, it may be different pairs of vowels.

2.3 The future of the Anyi acoustic vowel space

What does the future hold for the phonemic inventory of Anyi vowels? How long before the acoustic vowel space is completely reduced to an eight-vowel system? Will the acoustic vowel space be reduced further to a seven-vowel system? Becker-Kristal (2010: 113) discusses a possible scenario that may be in store for Anyi:

> They [vowels] might fall closer to other vowels, which are repelled further, albeit by a smaller magnitude, and this process propagates as a push chain shift with gradual decay through other vowels until the entire system finds a new balance.

What will the new balance look like for Anyi? It is hard to predict the future. However, we can anticipate what the Anyi Morofu vowel space will look like in the near future by learning from the current state of vowels in some languages in the Akan family. Mensah (1983: 430) reports that Krobou, another Akan language, has reduced the number of its vowels from nine to eight. It no longer has the vowel [ɪ], which has been replaced by [e]. If Anyi finds a new balance in an eight-vowel system, this balance will be temporary because another shift is afoot. The data in Table 6 shows that the next vowel targeted for disappearance is [ʊ] (523Hz):

It will most likely be replaced by [o] (477 Hz). The acoustic distance between them is 46 Hz. This merger may take a little while, but it is inevitable. Only Speakers 2 and 4 mark a clear contrast between these two vowels. Intelligibility is compromised in the speech of Speakers 1, 5, and 8. A merger has already taken place in the pronunciation of Speakers 3,

Table 6: The Impending Merger of [ʊ] and [o]

F1	[ʊ]	[o]	Distance
Speaker 1	539	481	58
Speaker 2	595	429	166
Speaker 3	431	414	17
Speaker 4	583	429	154
Speaker 5	510	469	41
Speaker 6	546	556	10
Speaker 7	506	544	38
Speaker 8	491	445	46
Speaker 9	545	544	1
Speaker 10	490	468	22
Mean	523	477	46
Standard Deviation	48	52	57

6, and 9; and it is on the verge of happening for Speaker 10. The merger between [ʊ] and [o] has already taken place in Baule, which is closely related to Anyi. Kouadio (1983: 284) reports that Baule no longer has [ɪ] or [ʊ]. Other languages in the Akan family spoken in Côte d'Ivoire have a seven-vowel system instead of the nine traditionally associated with this language family. Hérault (1983: 262) reports that Avikam has lost both [ɪ] and [ʊ], and so has Ebrie (Bole-Richard 1983: 324). The acoustic vowel space of Anyi Morofu will achieve stability when the number of its vowels goes from nine to seven.

3 Summary

The vowel spaces of languages are always shifting. English underwent a major shift between 1400 and 1600 (Fromkin et al. 2014: 342)). This change has been nicknamed the Great Vowel Shift. Labov et al.'s (2006) voluminous *ANAE* shows that another shift known as the Northern Cities Shift is slowly but surely fanning across the Midwest. Since change is a language universal process, one would expect the vowels of Anyi to also shift. The vowel [e] is masking [ɪ] for now. How long will it take for [ɪ] to be swallowed up by [e]? It is hard to tell. However, the process that is underway is almost irreversible given what has taken place in other Akan languages that are closely related to Anyi Morofu. For now Anyi is following the same path as Krobou. In a not so distant future, the shift from [ʊ] to [o] will run its course, and Anyi will have seven vowels like Baule and other Akan languages spoken in Côte d'Ivoire. However, synchronically, Anyi is in a between and betwixt state which causes it to be atypical, that is, it does not conform to PPS as predicted by CVS and DFT.

References

Abercrombie, David. 1985. Daniel Jones' teaching. In Victoria Fromkin (ed.), *Phonetic linguistics: Essays in honor of Peter Ladefoged*, 15–24. Orlando: Academic Press.

Becker-Kristal, Roy. 2010. *Acoustic typology of vowel inventory and dispersion theory: Insights from a large cross-linguistic corpus*. Los Angeles, CA: UCLA Doctoral dissertation.

Bole-Richard, Remy. 1983. L'ebrie. In Georges Hérault (ed.), *Atlas des langues Kwa de Côte d'Ivoire*, vol. 1, 307–357. Abidjan, Côte d'Ivoire: Institut de Linguistique Appliquée.

Everest, Alton F. & Ken C. Pohlmann. 2015. *Master handbook of acoustics*. 6th edn. New York: McGraw Hill Education.

Ferrand, Carole T. 2007. *Speech science: An integrated approach to theory and clinical practice*. 2nd edn. New York: Allyn & Bacon.

Fromkin, Victoria. 1985. *Phonetic linguistics: Essays in honor of peter ladefoged*. Orlando: Academic Press.

Fromkin, Victoria, Robert Rodman Rodman & Nina Hyams. 2014. *An introduction to language*. 10th edn. New York: Wadsworth Cengage Learning.

Fry, Dennis Butler. 1979. *The physics of speech*. Cambridge: Cambridge University Press.

Hérault, Georges. 1983. L'Avikam. In Georges Hérault (ed.), *L'Avikam*, vol. 1, 255–276. Abidjan, Côte d'Ivoire: Institut de Linguistique Appliquée.

Koffi, Ettien N. 2004. Oral vowels in nasalization contexts in Anyi: Implications for orthography. *Trends in African Linguistics* 6. 163–170.

Koffi, Ettien N. 2009. *The interface between phonology and morpho(phono)logy in the standardization of Anyi orthography*. Bloomington, IN: Indiana University. http://orthographyclearinghouse.org/index.php/. Revised doctoral dissertation.

Koffi, Ettien N. 2013. The acoustic vowel space of Central Minnesota English: Focus on intelligibility. *Linguistic Portfolios* 2. 2–16.

Koffi, Ettien N. 2014. The acoustic vowel space of Central Minnesota English in light of the Northern cities shift. *Linguistic Portfolios* 3. 2–20.

Kouadio, Jérémie N. 1983. Le Baoule. In G. Hérault (ed.), *Atlas des langues kwa de côte d'ivoire tome*, vol. 1, 277–306. Abidjan, Côte d'Ivoire: Institut de Linguistique Appliquée.

Labov, William, Sharon Ash & Charles Boberg (eds.). 2006. *Atlas of North American English: Phonetics, phonology, and sound change*. New York: Mouton de Gruyter.

Labov, William, Ingrid Rosenfelder & Josef Fruehwadl. 2013. One hundred years of sound change in Philadelphia. *Language* 48. 30–65.

Ladefoged, Peter. 1996. *Elements of acoustic phonetics*. 2nd edn. Chicago: The University of Chicago Press.

Ladefoged, Peter. 1999. American english. In *Handbook of the international phonetic association: A guide to the use of the international phonetic alphabet*, 41–50. New York: Cambridge University Press.

Ladefoged, Peter. 2003. *Phonetic data analysis: An introduction to fieldwork and instrumental techniques*. Malden, MA: Blackwell Publishing.

Ladefoged, Peter & Keith Johnson. 2015. *A course in phonetics*. 7th edn. Stamford, CT: Cengage Learning.

Maddieson, Ian. 1984. *Patterns of sounds*. Cambridge University Press: New York.

Mensah, Emanuel N. A. 1983. Le Krobou. In Georges Hérault (ed.), *Atlas des langues Kwa de Côte d'Ivoire*, vol. 1, 425–463. Abidjan, Côte d'Ivoire: Institut de Linguistique Appliquée.

Quaireau, André. 1987. Description de l'Agni: Des Parlers Moronou, Ndénié et Bona: Université de Grenoble III Doctoral dissertation.

Retord, Georges L. A. 1980. *Etude radiocinématographique des articulations de l'Agni-Sanvi*. Paris Doctoral dissertation.

Ryan, Kevin. 2005. *Grid-maker. Praat*. no address: no publisher. http://phonetics.linguistics.ucla.edu/facilities/acoustic/praat.html.

Schwartz, Jean-Luc, Louis-Jean Boe, Nathalie Vallée & Christian Abry. 1997. The dispersion-focalization theory of vowel systems. *Journal of Phonetics* 25. 255–286.

Thomas, Erik R. 2011. *Sociophonetics: An introduction*. New York: Palgrave Macmillan.

Welmers, William E. 1973. *African Language Structures*. Paul F. A. Kotey & Haig Der-Houssikian (eds.). Los Angeles, CA: University of California Press.

Yoon, Tae-Jin. 2008. *Stress-analysis. Praat*. http://web.uvic.ca/~tyoon/resource/vq.praat.