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HAUSA VOWELS AND DIPHTHONGS*

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Acoustic properties of Hausa vowels and diphthongs from several speakers are investigated. The results show that Hausa is best described as having a five vowel system, where the five basic vowels have the qualities of the long vowels. Long vowels are derived as double basic vowels. The qualities of the short vowels are significantly different from those of the long vowels, but these quality differences can be accounted for by an undershoot mechanism in the speech production. The diphthong /au/ is modeled, using the formant frequencies of /a/ and /u/ with an interpolation in accordance with a trinomial equation. The diphthong /ai/ is mostly realized as a long [e:] phonetically.

1. Introduction

In this paper acoustic data on vowels and diphthongs in Hausa are presented. Two topics are discussed in relation to these data, namely the relation between long and short vowels, and the nature of the diphthongs, as well as what kind of model can best describe the diphthongs.

Hausa belongs in the Chadic branch of the Afroasiatic language family. Chadic languages in general are characterized by few contrasting vowel phonemes with an abundance of environmentally conditioned allophones. Hausa has five contrasting long vowels: ii, ee, aa, oo, uu, and five short vowels: i, e, a, o, u . In addition there are two diphthongs, /ai/ , and /au/ . The occur-

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rence of short /e/ and short /o/ in non-final position is marginal and restricted to loanwords, e.g. from English. These vowels are not included in the study. The phonemic contrast between short /i/ and short /u/ in non-final position is questionable. Parsons [1970] and Schuh [1971] suggest that in non-final position the only contrasting short vowels are a low /a/ and a high vowel that varies between [i] and [u], depending on environment. Following Salim [1977] and Newman [1979] I will consider short /i/ and short /u/ to be phonemes. In addition, Hausa is usually described as having two diphthongs, /ai/ and /au/.

The Hausa syllable structure is fairly simple. A syllable can be "heavy": CVV, or CVC; or "light": CV. Vowel length is contrastive, but this contrast is restricted to open syllables. In closed syllables only short vowels can occur. Long geminated consonants occur phonetically across contiguous syllables, when the syllable-final consonant in one syllable is identical to the syllable-initial consonant in the following syllable in sequences of the type CVC-CV.

2. Procedure

A set of disyllabic words was selected to illustrate vowels and diphthongs in the first syllable. The data set was not designed to cover vowels in all possible positions. The environments for vowels were mainly restricted to initial labial and alveolar consonant(s) and medial alveolar consonant(s), which were in turn followed by /a/. The mid vowels occurred only after alveolar consonants. The selected items thus consisted of real disyllabic words of the type:

$$\left\{\begin{array}{l}\text{labial C}\\ \text{alveolar C}\end{array}\right\}\ \text{V(V) alveolar C(C) a(a)}$$

These words were put in a frame:

/bàn cêe CVCV ba/ 'I did not say...' or
/bàn cêe yaa CVCV ba/ 'I did not say he...(verb)'

In addition, a limited set of vowels after initial palatal and velar consonants and h were included. Most of the measured vowels and diphthongs in the first syllable were on high tones. See Appendix 1 for wordlist.

Ten speakers of Kano Hausa recorded these utterances in Kano. Measurements were made from wideband spectrograms of the durations and formant frequencies of the vowels. All measurements were made twice, six months apart. Vowel and diphthong durations were measured in milliseconds as the duration of the first formant. The durations of the steady state and transitional parts of the diphthong /au/ were measured from the second formant. Durations of the intervocalic medial plosives were also measured. This duration was taken to be the closure plus the release. Paired t-tests were used to determine the statistical significance of durational differences. Formant frequencies were measured from steady states of the vowels. If a vowel contained no steady state, its frequencies were taken from the middle of the vowel. Most vowels are represented by a couple of words in the wordlist with the vowel between consonants of the same place of articulation. The formant frequencies of each vowel between consonants of the same place of articulation were averaged for each speaker. The formant frequencies were measured in Hertz, then plotted on an acoustic chart with F1 against F2 on a mel scale in order to better correspond to perceptual distances. Ellipses with centers on the mean F1 and F2 for each vowel and with radii of two standard deviations were drawn along axes that were oriented along the principal components of each vowel distribution. Such an ellipse encompasses approximately 95% of the variation in each cluster.

3. Results and Discussion

3.1. Length. The durations of high and low vowels for the ten speakers were studied in the environment before alveolar plosives. The data consist of long /ii/ and /aa/ and short /i/ and /a/ in both open and closed syllables before voiceless alveolar plosive /t/ . The low vowel /a/ was measured in the environment before voiced alveolar plosive /d/ as well. The data came from words with the following syllable structures: CV, CV-CV, CVC-CV. The mean durations of the vowels and the alveolar consonants of the ten speakers have been plotted in Figure 1 (see next page).

Average durations in milliseconds of long and short /ii/ and /i/ before /t/ , and long and short /aa/ and /a/ before /t/ and /d/ for ten speakers are listed in Table 1 (see next page).

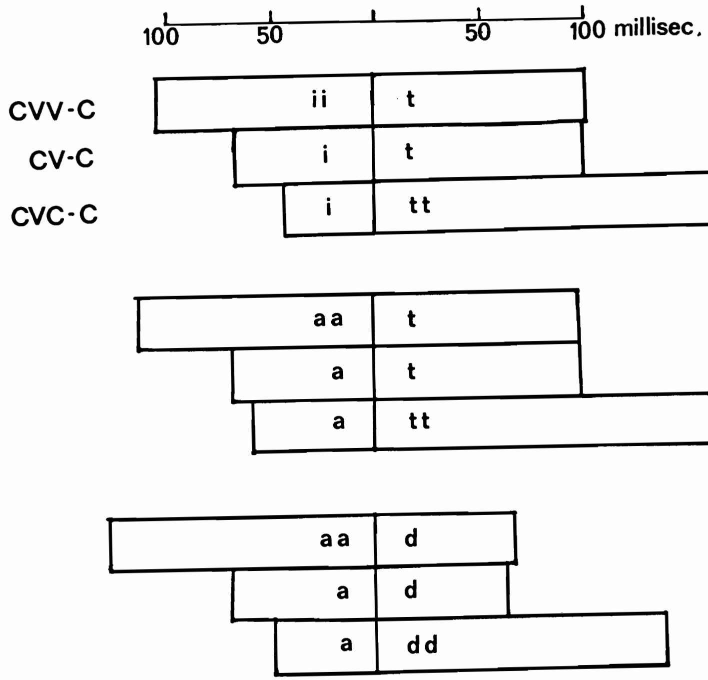

Figure 1. Bargraphs of the mean medial vowel and consonant durations of ten speakers in the three syllable types CVV-C, CV-C, and CVC-C.

msec.	/ii-t/	/i-t/	/it-t/	/aa-t/	/a-t/	/at-t/	/aa-d/	/a-d/	/ad-d/
$\bar{x}$	106	67	46	118	71	61	127	70	52
SD	18	16	15	15	8	6	16	11	12
	n=10								

Table 1. Means and standard deviations of the durations of /ii/ and /i/ before voiceless alveolar plosive, and /aa/ and /a/ before voiceless and voiced alveolar plosive for ten speakers. The short vowels in open and closed syllables are listed separately.

Hausa has three significantly different phonetic vowel lengths: long vowels; short vowels in open syllables; and short vowels in closed syllables. In open syllables the durational differences between long and short vowels are quite large. Roughly speaking, the long /ii/ and /aa/ are about 40-45% longer than the short vowels. These results for vowels in medial position are very similar to quantity relationships for vowels in final position, as shown by Newman and VanHeuven [1981]. In medial position, the differences in duration between short vowels in open syllables and short vowels in closed syllables are less than those between long and short vowels in open syllables, but they are still significant ($p<0.001$). The open syllable short /i/ and /a/ are about 15-20% longer than the ones in closed syllables. The durations of /uu/ and /u/ were also measured, but the data did not include these vowels in the environment before alveolar plosives. The measurements of the high rounded vowels were taken from the environment before alveolar liquids. Although the results are not directly comparable to those of /ii/-/i/ and /aa/-/a/ , they nevertheless conform to the same general pattern. The mean duration of /uu/ was 110 ms. The mean duration of /u/ in open syllable was 45 ms, and in closed syllable it was 35 ms. Thus, in this environment, the long /uu/ is about 59% longer than short /u/ in open syllable, and the short /u/ in open syllable is about 22% longer than in closed syllable.

In many languages there exists a compensatory relationship between vowel length and voicing in the following consonant. Vowels tend to be shorter before voiceless than before voiced consonants, and postvocalic voiceless consonants are usually longer than voiced consonants. In Hausa, however, the situation is more complex. As in most languages the postvocalic voiceless plosives are significantly ($p<0.001$) longer than their voiced counterparts. One might expect that at least the vowels in closed syllables should exhibit vowel shortening before voiceless consonants. But instead only the long vowels in open syllable follow the expected pattern and are significantly ($p<0.01$) shorter before voiceless than before voiced plosives. The durations of the short vowels do not differ significantly before voiced and voiceless consonants. In fact, if anything there is an unexpected weak tendency for the opposite relationship in that the short vowels in closed syllable tend to be *longer* before voiceless than before voiced consonants ($p<0.05$). It has been proposed that the compensatory relationship between vowels and voicing in postvocalic consonants is universal and therefore not part of the grammatical rules of individual languages [Chomsky and Halle 1968]. But there is now a considerable body of evidence that this relationship is not found in all languages and that it can be highly language-specific, e.g. Port et al. [1980]. The results from Hausa support the view that it is necessary to have language-specific rules for temporal patterning. In Hausa, only the long vowels in open syllable display the expected durational differences before voiced and voiceless consonants.

The double consonants are geminates. They are considerably longer than the corresponding single consonants. The durational differences are larger between the voiced long and short plosives than between the voiceless pairs. The medial /dd/ is more than twice as long as the /d/ , while the /t/ is about two-thirds of the length of the /tt/ .

3.2. Vowel quality. Figure 2 shows the F2 - F1 space on a mel scale for the long vowels. The data are from utterances where the long /ii/ , /aa/ , /uu/ occur after both labial and alveolar consonants, but the mid /ee/ and /oo/ occur after alveolar consonant only. The ellipse of the /oo/ is largely inside that of the long /uu/ , but the mean value of the first formant of /uu/ is lower than that of /oo/ , placing /uu/ as a somewhat higher vowel than /oo/ in this type of vowel space. As can be seen from the acoustic space in Figure 3, however, where the initial consonant environment is restricted to alveolar consonants, the higher extent of the /uu/-vowel is due to the additional labial consonant environment. When the first two formant frequencies of /uu/ and /oo/ after alveolar consonants only are compared by paired t-tests, it turns out that /uu/ and /oo/ do not differ significantly. The frequencies of the third formants were also compared for this vowel pair. As is common for high back vowels in general, the third formant of /uu/ was considerably weaker than for /oo/ , and was not visible on spectrograms in some cases. A grouped t-test was used for comparison of the formant frequencies. Their differences were not significant. Kano speakers thus do not distinguish between /uu/ and /oo/ in terms of what we usually call vowel quality. Many of the long /oo/'s

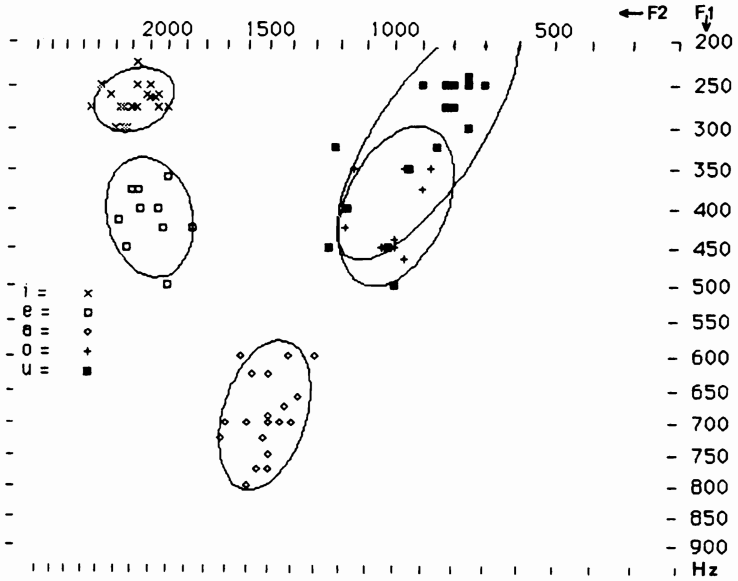

Figure 2. The formant space on a mel scale for the long vowels /ii/ , /ee/ , /aa/ , /oo/ , and /uu/ for ten speakers in the environment before alveolar consonant, and after labial and alveolar consonants.

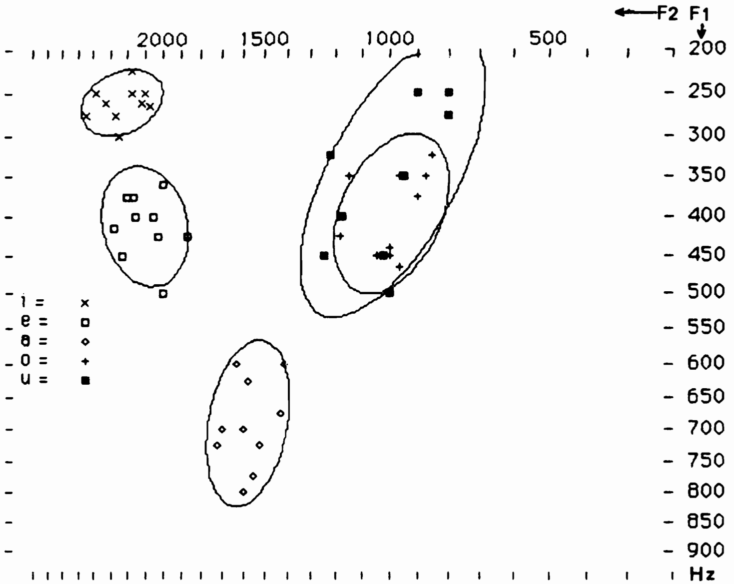

Figure 3. The formant space on a mel scale for the long vowel /ii/ , /ee/ , /aa/ , /oo/ , and /uu/ for ten speakers in the environment between alveolar consonants.

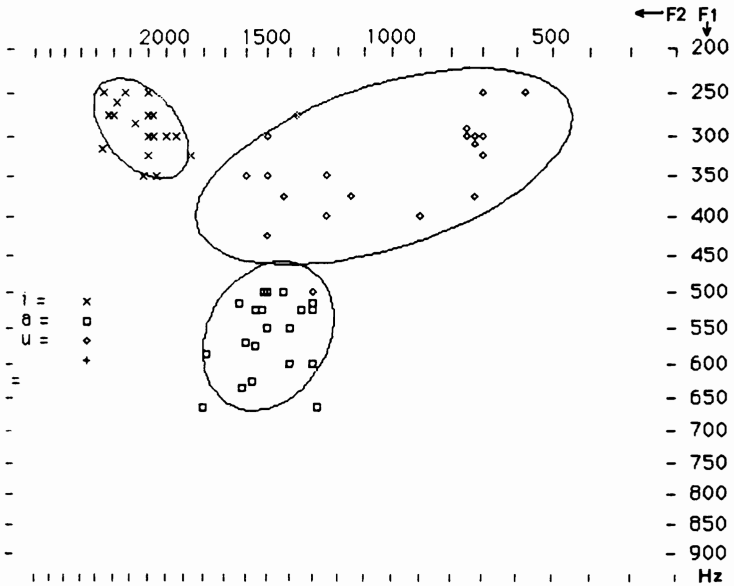

Figure 4. The formant space on a mel scale for the short vowels /i/ , /a/ , and /u/ in open syllable for ten speakers in the environment before alveolar consonant, after labial and alveolar consonants.

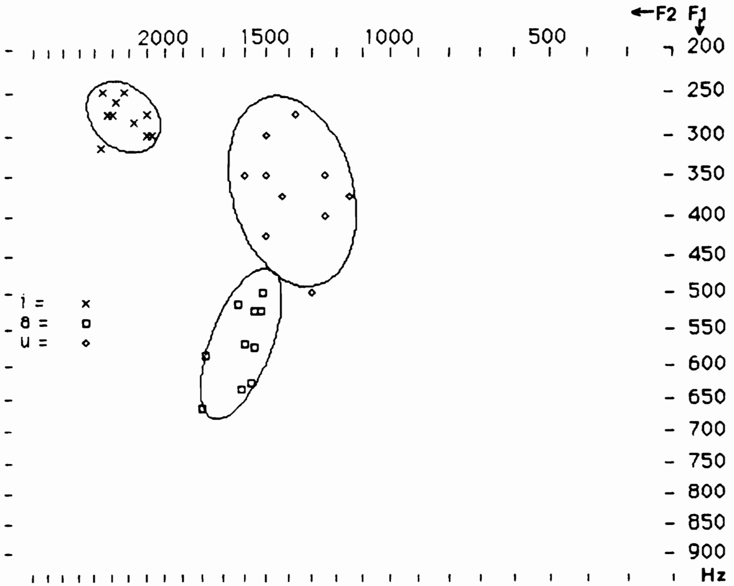

Figure 5. The formant space on a mel scale for the short vowels /i/ , /a/ , and /u/ in closed syllable for ten speakers in the environment between alveolar consonants.

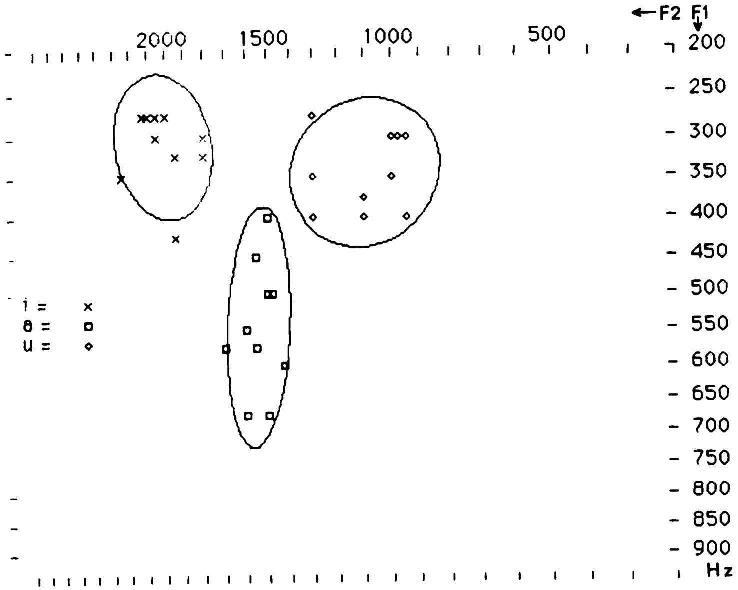

Figure 6. The formant space on a mel scale for the short vowels /i/ , /a/ , and /u/ in closed syllable for ten speakers in the environment between alveolar consonants.

developed historically from /uu/ in the environment of a following mid vowel [Newman 1979], so it seems almost as if the historical split of /uu/ and /oo/ is about to reverse itself.

The formant spaces for the short vowels are shown in the next three figures. Figure 4 illustrates the short vowels in open syllables after both labial and alveolar consonants, and Figure 5 in strictly alveolar environment. The short vowels in closed syllables in alveolar environment are shown in Figrue 6. In all these cases, the short vowels in both open and closed syllables are well separated in the acoustic space. If short /i/ and short /u/ were realizations of a single high vowel, one would expect to find considerable phonetic overlap when these vowels occur in similar environments as here. But instead these two high vowels do not overlap in either open or closed syllable. The phonetic evidence thus does not support the notion of neutralization between short /i/ and short /u/ . The two short high vowels may be allophones in complementary distribution in many environments [Schachter & Hoffman 1969, Chorier and Faraclas 1981], but in Kano Hausa these two vowels contrast in similar environments. Part of the reason for the large phonetic overlap between these two vowels may lie in the large intrinsic variation of the short /u/ . As shown by the relatively large size of the /u/-ellipse in Figures 4-6, there is considerably more variation between speakers for the short /u/ than for the other vowels, particularly in open syllable. Thus the short /u/ may be realized by some speakers as quite fronted, but it is still separate from the short /i/ . A large variability of high back vowels has been noted for many languages [Ladefoged 1967, Keating 1984]. The large amount of variation in the phonetic realization of short /u/ in Hausa is probably more due to this common tendency than to language-specific rules of Hausa,

3.3. Vowel duration and vowel quality. The qualities of the vowels show differences in the three vowel lengths. As in many other languages the long vowels are more peripheral than the short vowels. Paired t-tests between the formant frequencies of the long vowels and the short vowels in open and closed syllables demonstrate that the different vowel lengths, in most cases, are accompanied by different formant frequencies. Long /ii/ and short /i/ in both syllable types all differ significantly ($p<0.001$) along both F1 and F2: the short /i/'s are lower and more back than /ii/ . The long /uu/ and the short /u/'s all differ significantly ($p<0.001$) along F2, but not along F1. The high back vowels thus differ more importantly in the backness/rounding dimension than in the height dimension. The short low /a/-vowels in open and closed syllables are not significantly different, but the long /aa/ differs significantly ($p<0.001$) from both short /a/'s along F1. F2 is quite similar for all the low vowels. The long and short low vowels thus differ in the height dimension.

Thus in similar environments the three classes of vowels tend to differ significantly in duration and quality. The question arises whether the vowel quality differences are predictable from differences in vowel length, or have to be specified independently of length, as separate targets. This question has implications for phonology. If vowel quality differences result from differences in length because of an automatic process of vowel reduction which affects the short vowels and causes them to fall short of the target values achieved by the long vowels, then it argues for specifying Hausa vowels as five basic vowels, and separating out the treatment of length as an independent feature. It is possible to regard vowel reduction as an effect of "undershoot" in the production [Lindblom 1963]: the speaker aims at the same target for both long and short vowels, but due to lack of time the short vowels end up short of the intended target. The quality differences between long and short vowels then become results of mechanical constraints of the speech production mechanism. If the vowel quality differences cannot be treated as vowel reduction, then they must be regarded as phonologized, and two or three sets of underlying vowels must be posited, each set specified as to both duration and quality. In this case, each vowel is regarded as being stored with inherent information on quality and timing specified together in the form advocated in action theory of speech production [Fowler 1980]. The question at issue, then, is whether Hausa is best described as having long and short vowels with the same underlying qualities, the differences between the long and short variants being due to mechanical effects, or as having distinctive long and short vowel qualities?

If long and short vowels have the same target (intended quality), then one expects any remaining quality differences between long and short vowels to depend on the consonantal environment. There is a larger articulatory change in going from an alveolar consonant to a back rounded vowel than in going from a labial consonant to a rounded vowel. Conversely, there is a larger articulatory change in going from a labial consonant to a high front [i]-type vowel than in going from an alveolar consonant with a high tongue position to a high front vowel. In other words, the vowel in [di] will be less affected and closer to its target position than the vowel in [du], and the vowel in [bu] will be less affected than the vowel in [bi]. Acoustically, the transition from the low F2 locus of labial consonants to the high F2 of [i]-type vowels involves a much further distance than the transition to the low F2 of [u]-type vowels. The transition from the relatively high F2 locus of alveolar consonants to the low F2 of [u] is longer than to the high F2 of [i]. An undershoot account, in which it is postulated that corresponding long and short vowels have the same target thus predicts larger acoustic differences in F2 between /ii/ and /i/ after labial consonants than after alveolar consonants and larger F2 differences between /uu/ and /u/ after alveolar consonants than after labial consonants. An account that allows a long vowel to have a different target from a short vowel will not make this prediction.

Paired t-tests were applied to the differences in F2 between /ii/ and /i/, and between /uu/ and /u/, in each case after labial and alveolar consonants. Table 2 shows the results.

ii-i	after alveolar consonant	5 Hz	(NS)
	after labial consonant	113 Hz	($p<0.001$)
uu-u	after alveolar consonant	393 Hz	($p<0.001$)
	after labial consonant	65 Hz	(NS)

Table 2. F2 differences in Hz between long and short high vowels after alveolar and labial consonants.

The results are consistent with an undershoot type account. The second formant differences are significant when the consonant-to-vowel transition involves a relatively large distance, so that the short vowel ends up short of the intended target. When this transition involves a small distance the vowel quality can be reached in the short vowel as in the long vowel. The quality differences between long and short vowels may thus be accounted for by the mechanics of the speech production system operating on five basic targets. The Hausa vowels can be described as a basic five vowel system where the basic vowels have the qualities that appear in phonetically long vowels. The long vowels are derived as double vowels by stringing two of the same basic vowels together, e.g. /ii/. The qualities of the short vowels are derived from the basic vowels by way of application of vowel reduction rules that result in undershoot of the targets.

In addition to the above quality differences resulting from durational differences, Hausa vowel qualities also vary depending on their consonantal environments. Here I just want to mention a few tendencies noted in the data. As is implied by the above discussion, vowels in alveolar environments are further front than the same vowels in a labial environment, and vowels in velar environment tend to occupy a space between the vowels in alveolar and labial environments. Back vowels after laterals are more front than back vowels after other alveolar consonants. The laterals seem to have a fronting effect on back vowels, though not on front vowels. Front vowels are more front after palatal consonants than after other consonants. Low vowels after /h/ are lower than after other consonants.

4. Diphthongs

The nature of diphthongs in general is a little studied topic. Most of the units that are labeled diphthongs in the languages of the world are derived from underlying sequences of vowels, or from sequences of a vowel and a glide. Their phonetic realizations can be quite different in different languages. The relationship between the component parts of diphthongs may vary. In some languages the transition between the vowel components constitutes a major part of the diphthong, in other languages this transition is quite fast, and the major part of the diphthong consists of relatively steady vocalic states surrounding the transition. Consider /ai/ and /au/ in a few languages where data are available. In American English and Peking Chinese the transition occupies a major part in these diphthongs, while in Cairo Arabic, the transition is very fast. In American English the transition provides about 60% of the duration of /ai/ and 75% of /au/ (measurements from data in Gay [1968]), and in Chinese it provides about 50% of /ai/ [Svantesson 1984]. In Cairo Arabic, on the other hand, the transition occupies only 15% of /ai/ and 25% of /au/ (measurements from data in Norlin [1984]). The durations and the relationships between the component parts of a diphthong must thus form part of the phonological rules of a language.

4.1. Hausa /au/.

The /au/ in Hausa is always pronounced as a diphthong. Figure 7 illustrates typical examples of /au/ from two speakers (see next page). From an acoustic point of view it can be described as two vowels con-

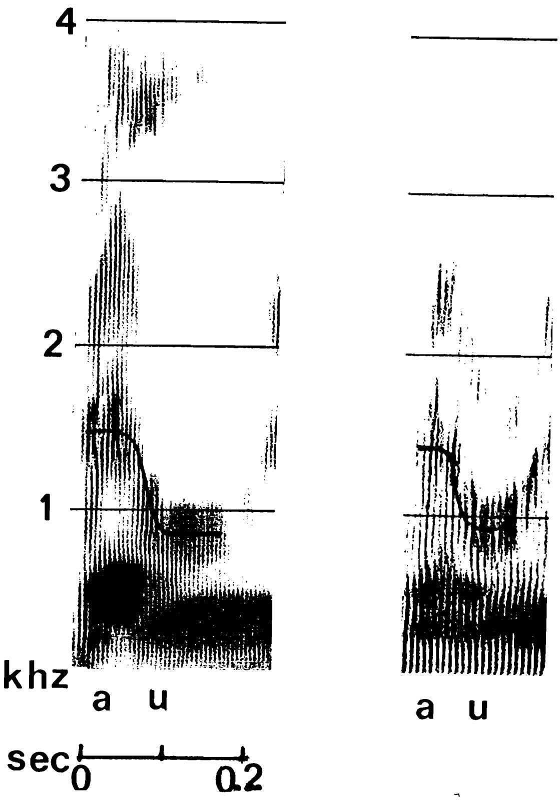

Figure 7. Spectrograms of the /au/ diphthong for two speakers.

nected by a transition. In addition, there are transitions from and towards surrounding consonants. As these consonant-to-vowel and vowel-to-consonant transitions presumably are not specific to the diphthong, but follow the same rules as for other vowels, they will not be considered in detail here. The questions of concern are the following: What are the acoustic properties of the vowel components of the diphthong? What kind of model can characterize the acoustic properties of the diphthong?

The vowel qualities of the component parts of the diphthong vary in the same way as other /a/'s and /u/'s in Hausa depending on the surrounding consonants. Restricting the diphthong to one environment, between alveolar conso-

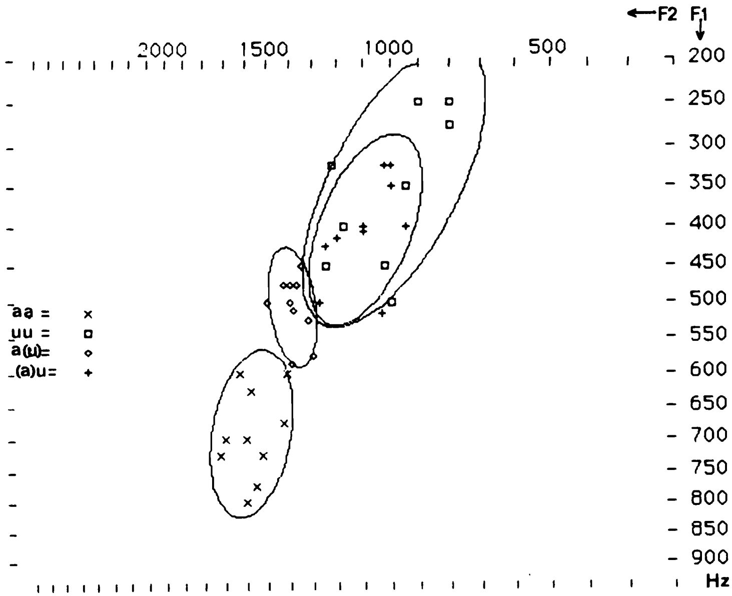

Figure 8. Formant chart of the [a] and [u] parts of /au/ , and of /aa/ and /uu/ in alveolar environment for ten speakers.

nants, the vowel qualities of the vowels comprising the diphthong are shown in Figure 8. For comparison, /aa/ and /uu/ from the same environment are also included. The onset of /au/ is a low vowel, although it is not as low as /aa/ . The quality of the offset vowel approaches that of /uu/ . The vowel qualities in /au/ can be derived from the basic /a/ and /u/ in the same way as the qualities of the short vowels by applying vowel reduction rules that result in undershoot of the target qualities due to limitations in duration.

The mean duration of the diphthong in these data is 185 msec. This is considerably longer than the duration for long vowels. The main reason for the diphthong being so much longer here is probably because the diphthong was measured before an alveolar tapped r-sound in zaurè 'entrance', and vowels before r-sounds tend to be longer than before plosives. It is also possible that the transition between the vowels in the diphthong adds to its length. The diphthong /au/ can be described as having four parts: a steady state part of /a/ , a vowel-to-vowel transition, a steady state part of /u/ , and a vowel-to-consonant transition. The steady state portions of the vowel components occupy roughly 30% each of the diphthong (the mean duration is 55 msec. each). For seven out of the ten speakers the transition between the vowels is quite rapid: 20-35 msec. This is about 15% of the diphthong. The remaining three speakers have a considerably longer transition. These three speakers were excluded from consideration here. For most Hausa speakers, however, their /au/ is similar to that in Cairo Arabic but different from that in American English and Chinese, where the transition constitutes a much larger part of the diphthong. The transition from /u/ to the following alveolar consonant takes up the remaining 25% of the diphthong (its mean duration is 50 msec.).

The spectrograms of the diphthongs also show that F1 and F2 do not always move in synchrony. For most of the speakers the transition part of the diphthong occurs later in F1 than in F2. This F1 delay is about 20 milliseconds. I have also observed a similar F1 lag in spectrograms of American English /au/ for some, but not all speakers. Because the delay in F1 is not apparent in the diphthong in every speaker, it cannot be an inevitable effect of the mechanics of the speech production system. This phenomenon needs further investigation. At this stage I can only speculate that the F1 lag occurs because speakers make use of different timing relationships between lip, jaw, and tongue movements. The F1 lag is best accounted for by optional rules that some speakers make use of and others do not.

The Hausa diphthong can be derived from a string of two vowels. The vowel qualities and durations of this base form are those of the basic /a/ and /u/ . Rules of vowel reduction that centralize the vowel qualities (Figure 8), duration adjustments and transition insertions generate the phonetic [au] . For an acoustic output the mean formant frequencies of [a] and [u] are taken as input. The mean duration of the steady state of each vowel component is 55 msec. The mean duration of the transition between the vowels is 25 msec. The formant trajectories of the diphthong itself, i.e. excluding the consonant-to-vowel transition and the vowel-to-consonant transition, can be generated from four points, A, B, C, D, illustrated in Figure 9. A-B and C-D are the formant trajectories of the steady states, each 55 msec. long. The formant transitions between the two vowels do not form just a straight line, but follow

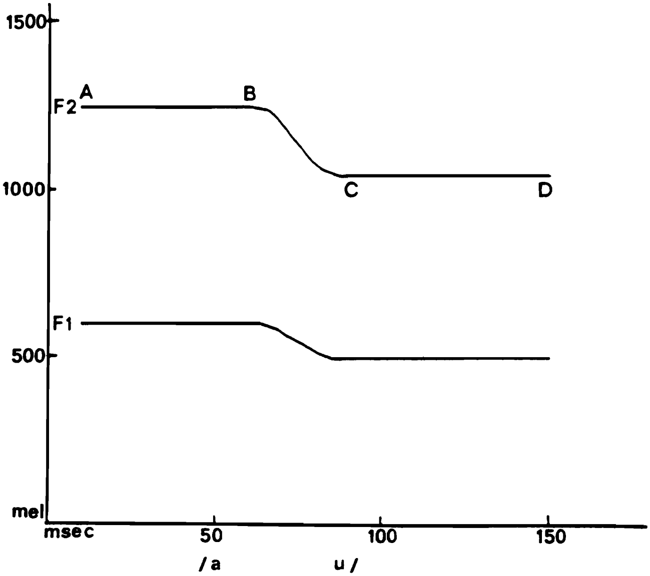

Figure 9. Acoustic model representation of the steady states and the vowel-to-vowel transition parts of Hausa /au/ , generated by rules discussed in the text.

an s-shaped trajectory. If the points B and C are considered as (t_1,y_1) and (t_2,y_2), then the interpolation is in accordance with a third order polynomial such that the velocity is zero at each end. Thus the program calculates the constants a_0, a_1, a_2, a_3 in a polynomial of the form:

$$y = a_0 + at + a_2t^2 + a_3t^3$$

by solving the following set of four equations with four unknowns:

$$y_1 = a_0 + a_1t_1 + a_2t_1^2 + a_3t_1^3$$

$$y_2 = a_0 + a_1t_2 + a_2t_2^2 + a_3t_1^3$$

$$\frac{dy_1}{dt} = 0 = a_1 + 2a_2t_1 + 3a_3t_1^2$$

$$\frac{dy_2}{dt} = 0 = a_1 + 2a_2t_2 + 3a_3t_2^2$$

where y = formant frequencies at time t.

Figure 9 is an acoustic representation of the essential parts of an average Hausa [au], generated by the above rules. In addition, there may be a possible, optional delay in the F1 transition. The transition from /u/ to the following consonant is not considered here.

This model of the Hausa /au/ is very general and can be applied to diphthongs in other languages. Diphthongs are represented as two vowels, /VV/, and they are generated by stepping from the first vowel to the second one through a transition. The formant frequencies of the vowel components and their durations are language specific, as is the duration for the transition. As was pointed out above, the transition duration in English and Chinese, for example, generally occupy a much larger part of the diphthong than in Hausa and Arabic. Given the duration of the transition, the formant trajectories can be generated using the equation for a third order polynomial.

4.2. Hausa /ai/. Although the diphthong /ai/ is symbolized as if it involved a considerable change in vowel quality, eight of the ten speakers pronounced /ai/ in labial and alveolar environments as a monophthong [e:]. The two remaining speakers used diphthongal pronunciations: [eɩ] in alveolar environment and [ʌɩ] in labial environment. A diphthongal [ɛɩ] pronunciation occurs for most speakers after /w/, as in ƙwai 'egg'. Figure 10 illustrates typical [e:] realizations of /ai/ on spectrograms of two speakers. Figure 11 is an acoustic chart of the [e:] realization of /ai/, as well as the realizations of /ii/ and /ee/, all from the environment of alveolar consonants. The [e:] realization of /ai/ occupies a higher position on the vowel chart than the [e:] realization of phonemic long /ee/. There is considerable overlap between these two phonetic [e:]'s but their mean formant frequencies are different. These differences are significant for both F1 and F2 (paired t-test: $p<0.005$). It is interesting to notice a speculation by Newman and Salim [1981] that the diphthong /ai/ should perhaps be derived from a long mid vowel that is different from the long /ee/. Newman and Salim symbolize this proposed underlying vowel /EE/. The strong tendency towards a monophthongal pronunciation of /ai/ and the differences in vowel quality between realizations of /ai/ and /ee/ provide some phonetic support for this

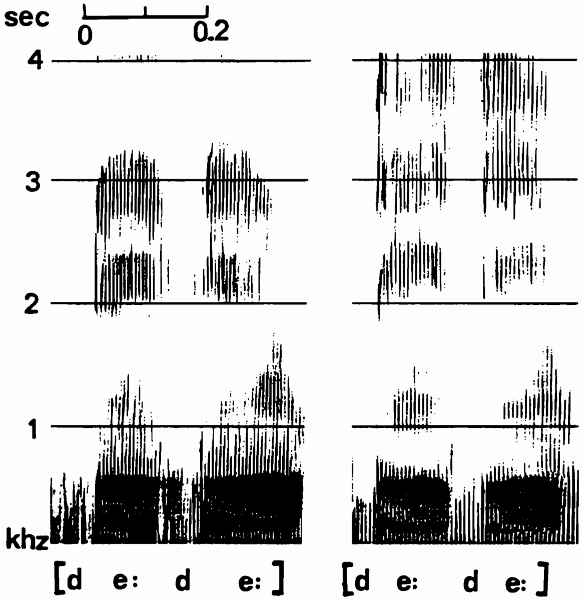

Figure 10: Typical [e:] realizations of /ai/ on spectrograms of two speakers.

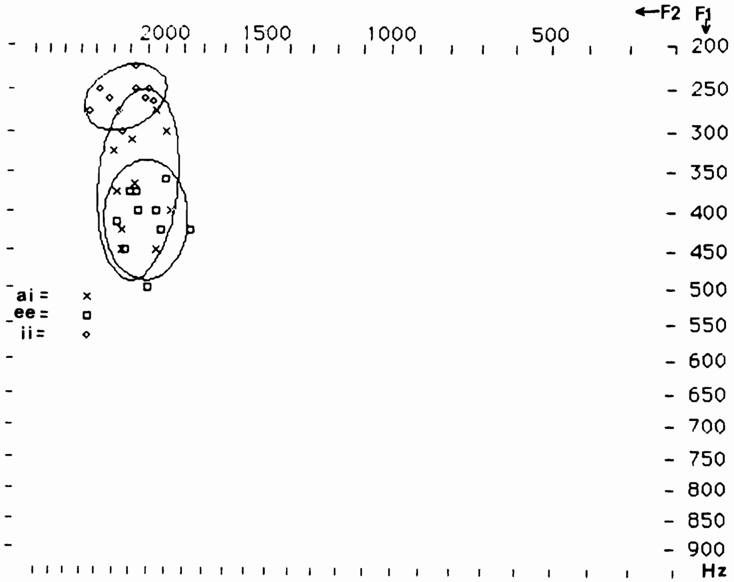

Figure 11. Formant chart of the [e:] realization of /ai/ , /ii/ and /ee/ for ten speakers in alveolar environment.

proposal by Newman and Salim.

5. Summary

Based on phonetic evidence the Hausa vowels are best described as five basic vowels. The long vowels are represented as doubled basic vowels. There is some indication that perhaps the /ai/ diphthong should be derived from a long front mid vowel that is different from /ee/ . The contrast between /uu/ and /oo/ seems to be in the process of being lost. The different qualities in the short vowels are derived by vowel reduction processes. The process for generating /au/ consists of stringing underlying vowels together in the same way as for generating long vowels. The results thus give phonetic support to an analysis of Hausa long vowels and the diphthong as /VV/.

APPENDIX 1: Wordlist

diilàa	'bale of cloth'	balàs	'balance'
liitàa	'litre'	gadàa	'bridge'
biiròo	'biro'	gazàa	'to fall short, to fail'
biitàa	n.f. 're-reading of text'	lazzàa	'pleasant taste'
dilàa	'jackal'	sallàa	'prayers'
tisàa	'to re-do, repeat'	sarcèe	'to combat'
bidàa	'thatching needle'	yaddà	'how'
birìi	'monkey'	haddàa	'memorization'
cìtaa	'to guess'	soosàa	'to scratch'
gidaa	'house'	lootòo	'time'
dìllaalìi	'broker'	koorèe	'green'
sistàa	'nurse'	luulàa	'to flee'
cittàa	'four days hence'	dùusaa	'bran'
teelàa	'tailor'	suusàa	v.n. 'scratching'
reetòo	n.m. 'dangling'	buudàa	'harmattan haze'
taadàa	'custom, tradition'	huutuu	'resting'
saalàa	'thin slice of meat'	tulàa	'pile up (earth)'
daazàa	'to trim an edge'	dutsèe	'grindstone'
faatàa	'skin, leather'	sulèe	'shilling'
ɓaatàa	'to spoil'	furaa	'millet-balls'
ƙaaràa	'to repeat'	kusa	'near, close'
jaajaa	'reddish'	surfàa	'to pound corn'
dasàa	'to plant out seedlings'	hujjàa	'reason, excuse'

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