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Vowels of the world's languages

Peter Ladefoged and Ian Maddieson

Phonetics Laboratory, Linguistics Department, UCLA, Los Angeles, CA 90024-1543, U.S.A.

Many of the vowels of the world's languages can be described simply by reference to the three traditional dimensions high–low, back–front, and rounded–unrounded, with the first two of these being considered as names for auditory dimensions. There may be up to five contrasting vowel heights. Some languages contrast otherwise similar front, central and back vowels. There are also two kinds of rounding: protrusion and labial compression. Minor vowel features include: nasalization, other tongue body features (advanced tongue root, pharyngealization, stridency, rhotacization, fricative), different phonation types (voiceless, breathy, laryngealized, creaky) and dynamic properties (long, diphthongal).

1. Introduction

This paper describes the parameters of vowel variation and reviews the kinds of vowel sounds that occur in the world's languages. But before we do this we should try to define what we mean by a vowel. In many linguistic descriptions sounds are classified as either vowels or consonants. The phonetic basis of this description is not straightforward. The best early work on this topic is that of Pike (1943) who began by splitting segments in another way. He first of all made a distinction between vocoids and contoids, with a vocoid being defined as a central resonant oral. He then went on to define a vowel as a syllabic vocoid. In practice this is very similar to the definition given by Chomsky & Halle (1968) in the latter part of *The Sound Pattern of English*. Their definition is that a vowel is a segment with the features [+syllabic, −consonantal], with [−consonantal] sounds being defined as those that do not have a central obstruction of the oral tract. In many ways this is functionally equivalent to the practice of contemporary autosegmental phonologists in defining a vowel as a [−consonantal] segment attached to a V slot. Whichever definition is used it is equivalent to saying that a vowel is defined by features that ensure that there are no major strictures in the vocal tract; and that it is syllabic.

We know what we mean by there being no obstructions in the vocal tract, but what, from a phonetic point of view, do we mean by syllabic? There is no phonetic parameter that can be used to define syllabicity in articulatory, or physiological terms. When Pike proposed his definition, he did so in the light of the research of Stetson (1928), implying that each syllable is associated with the particular kind of respiratory activity that Stetson called a "chest pulse". We now know that syllables are not necessarily associated with a chest pulse (Ladefoged, 1967); but phoneticians have not been able to suggest an alternative definition of the physiological

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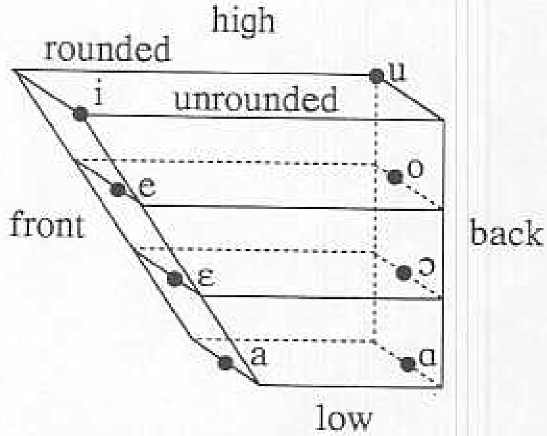

Figure 1. The dimensions of vowel quality.

properties of a syllable. The best that we can do is to suggest that syllables are 'necessary units in the organization and production of utterances' (Ladefoged, 1982). This is a neurophysiological, or cognitive view of the syllable, rather than a truly articulatory phonetic one. Perhaps we should not even try to provide a physiological phonetic definition of the syllable. Syllables are identifiable as the primary elements over which the rhythmic patterns of language can be observed, or the primary domain over which sequential constraints apply or coarticulatory adjustments can be made. That is, the syllable is a phonological unit. Accordingly we will be considering in this paper those sounds which have been called vowels because of their phonological function.

Many of the features required for linguistic descriptions of vowels have been established for some time. An excellent summary of their application to the world's languages was given by Lindau (1978). The discussion here will follow a similar framework; we will summarize our differences at the end of the paper.

The basic building blocks of most vowel systems are the three qualities that are traditionally called high–low, front–back and rounded–unrounded. Figure 1 shows the location of a set of reference vowels, the cardinal vowels described by Jones (1956), within the space defined by these dimensions. In our examination of the vowels of the world's languages we will continue to use the traditional terms high–low and back–front, and we will refer to these dimensions as Height and Backness (names of formal vowel parameters are capitalized throughout the paper to distinguish them from other uses of the same words). But although we are continuing to use the familiar articulatory labels, we will regard them as referring to auditory properties. This issue is discussed in more detail in Ladefoged (1990).

2. Vowel height

Variations in vowel quality often involve all three of the primary dimensions, Height, Backness, and Rounding. This sometimes makes it difficult to decide how many levels of Height there may be in a particular language. Consider, for example, the vowels of Italian, which can be represented schematically as in Fig. 2. There may be four vowel heights; but each vowel also varies along the front-back

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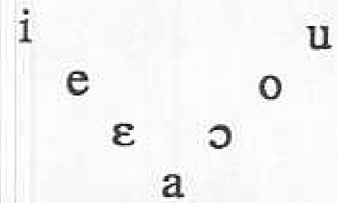

Figure 2. A schematic representation of Italian vowels.

dimension, and (although it is not apparent from the diagram) in the degree of lip rounding. Furthermore, the low vowel [a] does not contrast in the front–back parameter, and therefore provides little evidence for saying that there are more than three heights possible for front vowels or for back vowels.

Bearing this in mind, we will consider how many levels of height are used in the world's languages. Some linguists (e.g. Chomsky & Halle, 1968) have suggested that there only three (although, of course, these linguists recognize other dimensions which they use for representing what we regard as simply variations in height). Jones's (1956) Cardinal Vowel scheme makes reference to four particular levels of the Height dimension, but has provision for more possibilities. The full set of vowel symbols recommended by the IPA (1989) implies that there are seven levels. We doubt that any language uses this full range; but there are clearly more than three levels of the auditory property Height.

Evidence for the possibility of more than three contrasting vowel heights comes from Danish, in which there are four front vowels that contrast simply in vowel height. Examples are shown in Table I. It is noteworthy that each of these four vowel heights there is also a contrast between a short and a long vowel, which do not differ appreciably in quality. These vowels are even more interesting because it is quite clear that they are not equidistant. Uldall (1933) represents them as shown in Fig. 3. There is a much larger gap between the vowels represented here [ɛ] and [a] than there is between the vowels [i] and [e]. This raises the possibility that there might be a language with five vowel heights.

Traunmüller (1982) has suggested that the Bavarian dialect spoken in Amstetten, Austria, might be such a language. In his analysis this language has four front unrounded, four front rounded, and four back rounded vowels, in addition to the low central vowel [a]. Traunmüller conducted a controlled study in which he recorded a number of speakers of this dialect, and measured the acoustic characteristics of the 13 vowels so as to obtain an indication of the traditional height and backness values. The mean formant frequencies of eight of his speakers (as reported by Disner, 1983) are shown in Fig. 4. In this figure (as in all our vowel formant charts in this paper) the frequency of the first formant, F_1, is plotted against

TABLE I. Contrasts illustrating four degrees of vowel height in Danish

vilə	*wild (pl)*	viːlə	*rest*	viːðə	*know*
menə	*remind*	meːnə	*mean (vb)*	veːðə	*wheat*
lɛsə	*load*	lɛːsə	*read*	veːða	*wet (vb)*
masə	*mass*	maːsə	*mash*	vaːðə	*wade*

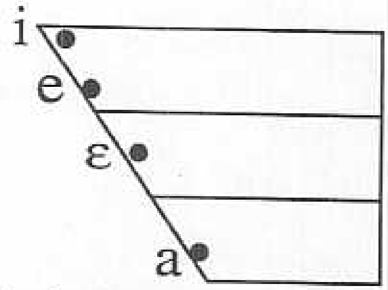

Figure 3. The relative phonetic qualities of the four front unrounded vowels of Danish, based on Uldall (1933).

the difference between the frequencies of the second and first formants, $F_2 - F_1$. The frequency values are scaled so that equal distances along either axis more nearly correspond to equal perceptual distances (using the Bark scaling techniques proposed by Schroeder, Atal & Hall, 1979). The scale on the ordinate is double that on the abscissa, as, in our view, this gives appropriate prominence to F_1 and makes the plots more in accord with the auditory judgments of professional phoneticians. The origin of the axes is to the top right of the plot. These plotting techniques (which are all incorporated in a computer program) produce vowel charts that are in good accord with traditional representations of vowels. We have not ourselves investigated the vowels of this dialect of Austrian German, and so we cannot say whether there are any other factors involved which might lead to it being possible to describe this language as having fewer than the five vowel heights that are apparent in Fig. 4.

All languages have some variations in vowel quality that indicate contrasts in the vowel height dimension. Even if a language has only two phonologically contrastive

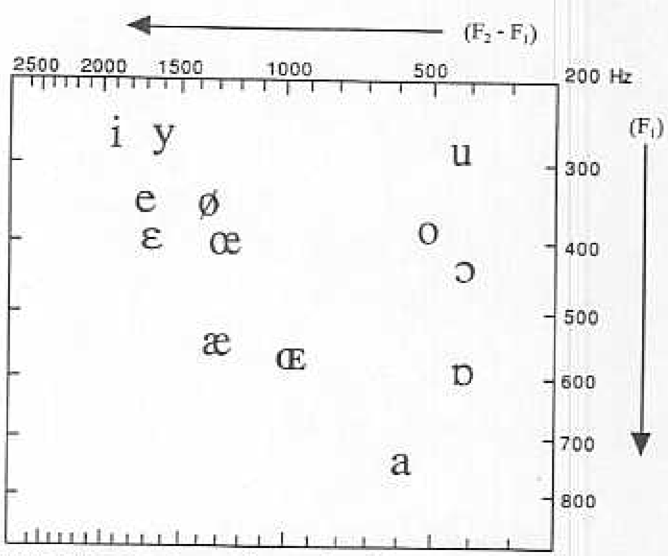

Figure 4. The mean formant frequencies of the vowels of eight speakers of the Amstetten dialect of Bavarian. (Data from Traunmüller, 1982.)

TABLE IV. Contrasting front, central and back rounded vowels in Norwegian

	Front	Central	Back
High, rounded	byː *town*	bʉː *shack*	buː *live*

three high rounded vowels, as shown in Table IV. Consideration of a number of very different cases, such as Ngwe and Norwegian, leads us to conclude that it is probably appropriate to recognize a front–back dimension containing three major phonetic categories: [front], [central] and [back]. There are also phonological reasons for saying that in languages with five vowel systems, and in many of those with seven vowel systems, the lowest vowel is neither front nor back, and should be regarded as central. This is often the position taken in descriptions of the vowels of Italian shown in Fig. 2. It is arguable that a similar situation obtains in English with respect to the starting points of the diphthongs in *high* and *how*. Despite the rules in Chomsky & Halle (1968), for many people these diphthongs have the same, or very similar, starting points. A generalization is lost if the inadequacies of the feature system do not allow one to say that both these diphthongs start with a low central vowel.

A rather unusual acoustic correlate of the front–back parameter occurs in a variety of /i/ in Swedish, which differs from the more usual varieties of [i] in that it is made with the constriction even further forward. This effect can be achieved by slightly *lowering* the body of the tongue while simultaneously raising the blade of the tongue (Ladefoged and Lindau, 1989), and we suggest that this may occur in the usual Stockholm Swedish pronunciation of these vowels. Acoustically they are characterized by having a very high F_3, and an F_2 which is *lower* than that in [e].

4. Rounding

The great majority of the world's languages have a predictable relationship between the phonetic Backness and Rounding dimensions. Front vowels are usually unrounded and back vowels are usually rounded. However, as shown above for Bavarian German, front vowels with a rounded lip position also occur. In addition, back vowels without lip rounding can be found, sometimes simply because a language has relaxed the linkage between Backness and Rounding (as for the high back vowel of Japenese), but also on occasion because rounded and unrounded vowels are independently contrastive within the class of back vowels, as in the Turkic languages Chuvash and Yakut.

Rounding and Height are also related in that higher vowels are usually more rounded than lower vowels. There are exceptions to this relationship. In Assamese there are two low back vowels with very similar formant frequencies, as can be seen in Fig. 6. In this word the second vowel, here designated as [ɔ], is a low back vowel fairly similar to the cardinal vowel [ɔ]. The first vowel, which we have transcribed with the symbol [ɒ˒], appears to have the tongue position of the low back cardinal vowel [ɑ], but a much closer lip rounding, more like that of [u]. The lower tongue position of the first vowel would, by itself, cause a raising of the frequency of the

TABLE II. Arrente vowel variations; column (1) is a phonological transcription of the two vowel system, column (2) is a narrow phonetic transcription of a recording, using current IPA symbols and diacritics (International Phonetic Association, 1989), in which an underline indicates retraction, and superscript cross indicates centralization

	(1)	(2)
elder brother	kakə	ka̠kɐ
cut	akəkə	a̠kəkɐ
head	kapəʈə	ka̠pəʈʌ
frog	ancəcərə	əncɪcə̽rɐ
nasal mucus	təŋkʷəlkŋə	təŋkʷʊlkŋʌ

vowels, the differences will always be in this dimension rather than the front–back dimension. Thus in native vocabulary, the Chadic language Margi has /ɨ, a/ and the Australian language Arrernte (Aranda) has /ə, a/. Among the Caucasian languages, Ubykh and Abkhaz have only two phonological vowel heights, with the contrasts usually represented as /ə – a/ (Catford, 1977*a*). None of these two-vowel languages makes any phonological use of the front–back, or the rounding, dimensions. The same is true of some of the other Caucasian languages, such as Kabardian, which have three phonologically contrastive vowels (not zero, one, or two as suggested by Kuipers (1960), Anderson (1978), and Halle (1970) respectively).

In all these cases of languages that have only height differences, there are also very obvious allophonic differences in the front–back dimension, so that to the

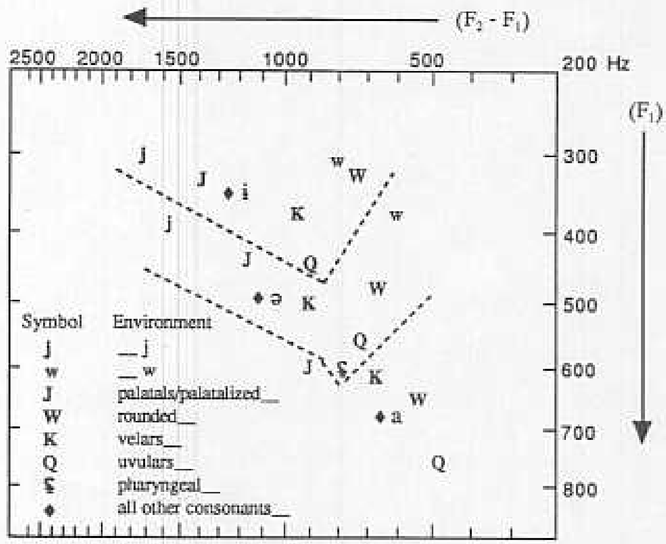

Figure 5. Mean formant frequencies of the three Kabardian vowels in different contexts as produced in connected speech by three speakers (from Choi, 1990). The symbols indicate the formant frequencies of the steady state portion in the contexts shown.

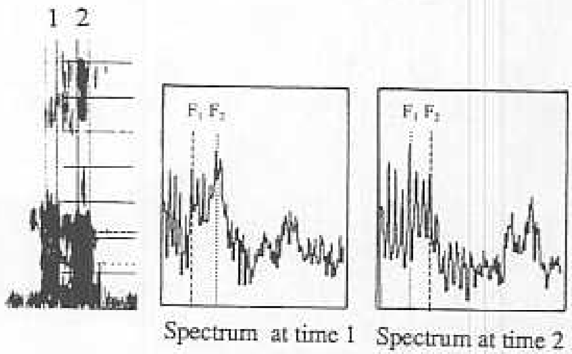

Figure 6. Spectra of two low back vowels in Assamese, [ɒ·] and [ɔ] as in [xɒ·hɔx] "courage".

first formant (and, perhaps, of the second formant). But this raising tendency is completely countered by the lowering effect of the lip rounding, which also results in a considerable decrease in the energy above the second formant amounting to approximately 35 dB between 1200 Hz and 2000 Hz. This sharp drop off is accentuated by the comparatively high intensity of this formant.

There are no clear-cut cases of three contrastive types of rounding. A possible case occurs in Swedish, in which there are three vowels which are all high and are all front, but which have different lip gestures. Examples of these vowels are shown in Table V. The symbol [ʉ] in this table is used to specify a high front vowel, rather than a high central vowel, which is its defined IPA value (and which is the value it has in specifying Norwegian vowels in Table IV). The precise quality of this vowel has been an issue for many years. Sweet (1877) in his *Handbook of Phonetics*, suggested that it was a high front vowel with a particular kind of rounding; but shortly afterwards, he noted that: "This vowel was wrongly analysed by me in my *Handbook*, and it was not till I had been some time in Sweden that I came to the conclusion that it was the ordinary European [u] with the inner (cheek-) rounding retained, but with the lips more open, seemingly in the low-round position of the English vowel in "fall" . . . the position is really the high-back [ʊ]" (Sweet, 1879, p. 379). Malmberg (1951 notes that: "This vowel has caused trouble for phoneticians for a long time . . . It may perhaps be best characterized by saying that it combines the half-close tongue position of [e] with a very special labialization (the lips are not protruded as much as for [y] but are contracted in a very characteristic way)" (Malmberg 1951, p. 46; our translation). Later Malmberg (1956, p. 317) notes that "recent x-ray studies have confirmed . . . (that) the slight difference in tongue position cannot be considered sufficient to differentiate [ʉ] from the [y:] and the [ø:] from which it is phonemically distinct". He goes on to state that Swedish has three

TABLE V. Swedish high front vowels varying in lip position. [y] has (horizontal) lip rounding and protrusion; [ʉ] has (vertical) lip compression

Protrusion	Compression	Neutral
ry:ta *roar*	rʉ:ta *window pane*	ri:ta *draw*

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casual observer it might appear as if the language used a wider range of vowel qualities. Table II shows, in the first column, a phonological transcription of some words in Arrente, illustrating the two constrastive vowels. The next column shows a narrow phonetic transcription of these words, giving an indication of the surface phonetic qualities.

As another example, Fig. 5 is a formant plot of the allophones of some Kabardian vowels analyzed by Choi (1990). As is shown by the location of the points on the chart, this language has a wider range of vowel qualities than is indicated by the use of just three symbols that represent only differences in vowel height. In Kabardian all these different qualities are predictable allophones of the three vowels, /ɨ, ə, aː/. It is also clear, as Choi (1990) points out in discussing this analysis, that Catford (MS) (and many Soviet linguists) are correct in recognizing /a/ as a third vowel. In Choi's view /aː/ is a long vowel, but it is a separate phoneme, and cannot be considered to be an allophone of /ə/ as suggested by Kuipers (1960) and Halle (1970).

3. Front–back variations in vowels

The languages of the world make much more limited use of the front–back and rounded–unrounded dimensions, which usually support no more than binary oppositions. There are not many cases of a language with three vowels that contrast just by being front, central and back, with all other features remaining the same. One possibility is Nimboran, a Papuan language. Anceaux (1965) describes this language as having six vowels which he symbolizes /i, e, a, o, u, y/. He notes that "all vowels are unrounded and voiced. They contrast in tongue height and tongue placement". The vowel /i/ "is a voiced high close front unrounded vocoid". His /y/, for which he says "the symbol . . . has been chosen quite arbitrarily and for practial reasons only", he describes as "a rather tense voiced high close central unrounded vocoid". We would transcribe this vowel as [ɨ]. He describes his [u] as "a voiced high close back unrounded vocoid", which we would transcribe as [ɯ]. It would therefore appear as if there were three high unrounded vowels contrasting only in backness in this language. Examples (from his data, but in our transcription) are shown in Table III.

Another language which can be said to have a three-way contrast in the front–back dimension is Norwegian, which is described by Vanvik (1972) as having

TABLE III. High vowels in Nimboran (based on Anceaux, 1965)

Front	Central	Back
di	'ɯndɨ	dɯ
wood	*banana*	*child*
ki	kɨ	kɯ
woman	*faeces*	*time, day*
kip	kɨp	'pakɨp
fire	*lime*	*lid*

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degrees of rounding ("flatness" in the Jakobsonian paradigm within which he was arguing). Fant's x-ray data on these vowels, which have been reproduced in small size in many publications (e.g. Fant, 1973, p. 11), are reproduced here in Fig. 7 in a larger size. The evidence they provide is not entirely in agreement with Malmberg's account. At least for this speaker, [ʉ] is much higher than the mid vowel [eː]. The three vowels [iː yː ʉ] have similar (although not identical) tongue positions; [yː] has a more open and more protruded lip position; [ʉ] has a fairly close approximation of the upper and lower lip, but without protrusion. In measurements of labial gestures of eight speakers of Swedish, Linker (1982) found that the same distinctions applied to her subjects. McAllister, Lubker & Carlson (1974), who came to a similar conclusion, also note that these high vowels have a consonantal offglide in Swedish; the offglide for [y] is the protruded semi vowel [ɥ], whereas [ʉ] has an offglide that they symbolize [β]. Vanvik (1972) also noted that [u] and [ʉ] in Standard Norwegian share the same lip position, whereas the third vowel [y] has protrusion. All these

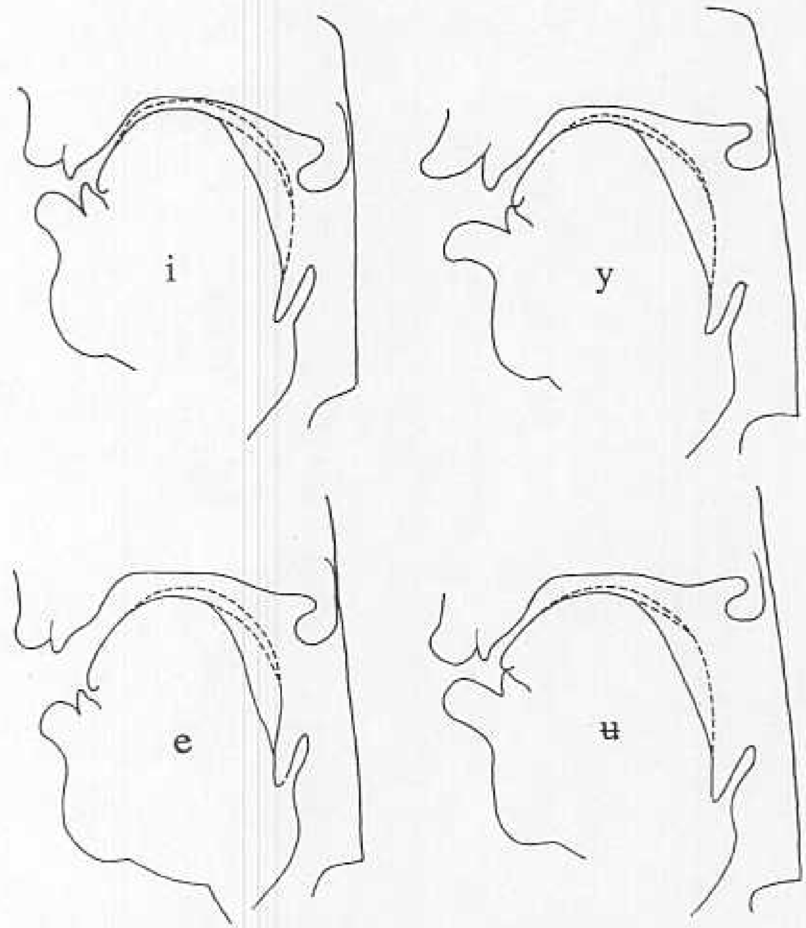

Figure 7. Swedish high front vowels varying in lip position. [y] has (horizontal] lip rounding and protrusion; [ʉ] has (vertical) lip compression. (After Fant, 1973).

observations, together with our own investigations of these languages, lead us to conclude that there are two lip position parameters for vowels, vertical lip Compression and Protrusion. In most languages these parameters are implemented jointly (and, also, linked to the front–back dimension), and it is sufficient to distinguish rounded (either compressed or protruded) vowels from unrounded vowels. In a small number of languages the two parameters are independently controlled. Some languages may choose to use lip compression rather than the form of rounding that has lip protrusion. Edwin Pulleyblank (personal communication) notes that Japanese /u/ can be regarded as having compressed lips rather than being simply unrounded. This vowel shows its labiality by the fact that it alternates with /w/ in verbal inflections. Pulleyblank also notes that the Japanese allophone of /h/ that occurs before /u/ is bilabial [ɸ], with what we here call compressed, rather than protruded, lips. We have not investigated the acoustic characteristics of lip compression. They are presumably similar to those of lip rounding and protrusion, differing with respect to the varying effect of the length of the vocal tract on the formant frequencies and amplitudes.

5. Major and minor features of vowels

Table VI summarizes the major vowel features and the major phonetic categories possible within each of these features. It should be noted that Height and Backness are multivalued, and cannot be adequately represented in binary terms.

The features and categories listed in Table VI might be taken to imply that there are $5 \times 3 \times 2 \times 2 = 60$ possible vowels differing only in the values of the major features of vowel quality. However, a number of combinations are so unlikely to occur that they might well be considered to be impossible. For example, there is no known language, and almost certainly could not be a language, which contrasts four lip positions among front low vowels; and it seems equally unlikely that there could be a language that contrasts five degrees of height among back unrounded vowels. It follows that the values shown in Table VI substantially over-represent the phonological possibilities.

They do not, however, allow for all the phonetic possibilities. In order to describe phonetic differences among vowel qualities that occur in different languages, a far greater number of distinctions must be considered. Disner (1983), for example, has shown that there are many small phonetic differences among the vowels that occur in different languages. Using her work, Ladefoged (1984) discussed systematic phonetic differences between two seven-vowel languages, Italian and Yoruba, both of which have vowels that may be represented as /i, e, ɛ, a, ɔ, o, u/. The mean

TABLE VI. The major features of vowel quality

Height	Backness	Rounding: Compression	Rounding: Protrusion
[high]	[front]	[compressed]	[protruded]
[mid-high]	[central]	[separated]	[retracted]
[mid]	[back]		
[mid-low]			
[low]			

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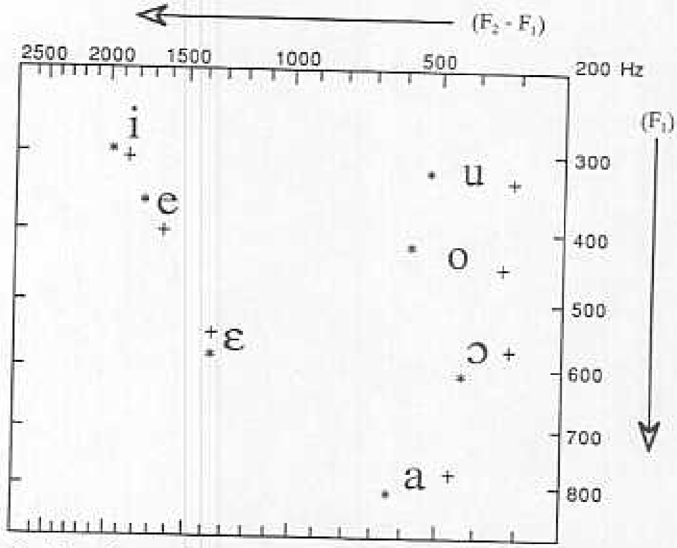

Figure 8. Mean formant frequencies of the vowels of Yoruba (*) and Italian (+).

formant frequencies of 25 speakers of Italian and 10 speakers of Yoruba are shown in Fig. 8. The vowels of Italian are evenly distributed; but in Yoruba /e/ and /o/ are much closer to /i/ and /u/ than to /ɛ/ and /ɔ/ respectively. The uneven distribution of the Yoruba vowels may be attributed to historical facts concerning the way in which the vowels of the original nine- or ten-vowel system (Fresco, 1970) have merged to produce the current seven-vowel Yoruba system. The earlier system may have involved an additional vowel parameter, ATR, which we will discuss later. Synchronically, however, Yoruba vowels can be described using only the major features of vowel quality which we have been discussing in the preceding sections. The set of terms given in Table VI is adequate for specifying the phonological contrasts within each of these languages, but not for discussing the phonetic differences between them.

The Yoruba and Italian differences, and many similar variations in vowel quality such as those among Germanic languages discussed by Disner (1983), are all examples of variations in the phonetic values of what we have called major vowel features. We will now turn to other ways in which vowels differ, considering mainly how these additional vowel properties may be used to form phonological contrasts within a language. We will refer to these additional properties of vowels as the

TABLE VII. The minor features of vowel quality

(1) Nasalization	(3) Voiceless Breathy Laryngealized Creaky
(2) Advanced Tongue Root Pharyngealization Stridency Rhotacization Fricative	(4) Long Diphthongal

minor vowel features. Table VII lists a number of additional properties that have been observed. As may be seen, they fall into four groups, only the first two of which will be discussed in detail in this paper. The first, and by far the most commonly found of the minor vowel features is nasalization. The remaining additional vowel features fall into three main groups: those that involve special gestures of the tongue and associated structures; those that involve different phonation types; and those that involve differences in the time domain, producing variations in length and diphthongization.

6. Nasalized vowels

The most common minor vowel feature is nasalization, with more than one language in five using this possibility (Maddieson, 1984). The most frequent nasalized vowels are [ĩ, ã, ũ], the counterparts of the most frequent oral vowels [i, a, u]. Nasalization appears to be a binary feature from a phonological point of view. But there are surface phonetic contrasts between oral, lightly nasalized, and heavily nasalized vowels in some languages. This usually occurs when a language with a phonological contrast between oral and nasalized vowels in addition has oral vowels that are contextually nasalized when adjacent to a nasal consonant. An example is shown in Fig. 9 (after Cohn, 1990) comparing the nasal flow patterns of the French words *bonnet, nonnette*, and *non-être* ("cap", "young nun", "nonentity"). The volume of air flowing through the nose can be taken as a measure of the degree of nasality when there are comparable oral articulations. Vowel (1) is an oral vowel before a nasal consonant, resulting in the last part of the vowel being contextually nasalized; vowel (2) is considerably more nasalized, as it is between two nasal consonants; but it is not as nasalized as vowel (3), a phonologically nasalized vowel, in the same context.

Using surface phonetic contrasts such as those shown in Table VIII, Merrifield (1963) and Ladefoged (1971) noted three degrees of contrastive nasality in Chinantec. This claim was supported by airflow data (recorded by W. S.-Y. Wang and Peter Ladefoged; unfortunately these data are no longer available) showing that there was a higher rate of airflow in the fully nasalized vowels than in the lightly nasalized vowels. There are, however, complications in this case in that there are differences in the relative timing of the onset and offset of nasality. The vowels that are lightly nasalized are in fact nasalized through only a part of their duration, as may be seen in Fig. 10. Here the vowel in the middle token can be seen to consist of

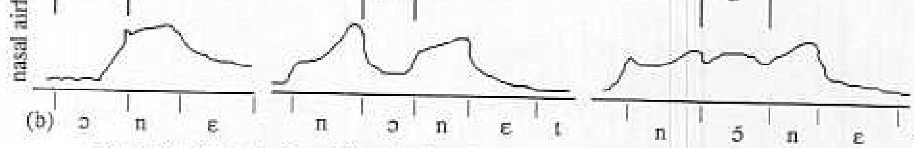

Figure 9. Records of nasal flow in three French words *bonnet, nonnette*, and *non-être* ("cap", "young nun", "nonentity"), showing the difference between oral, contextually nasalized and phonologically nasalized vowels (after Cohn, 1990).

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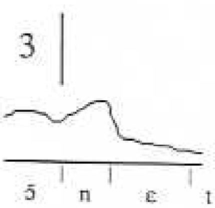

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TABLE VIII. Contrasts involving oral, partly nasalized, and nasalized vowels in Chinantec

ha *so, such*	ha^{ã} *(he) spreads open*	hã *foam, froth*

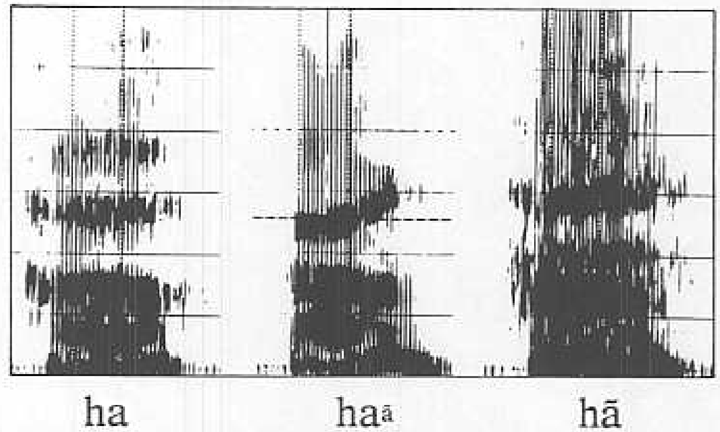


Figure 10. Spectrograms of Chinantec vowels. The horizontal grid lines are at 500 Hz intervals. (The vertical cursors delimit parts of the vowels used in other analyses not discussed here.)

a portion which is somewhat similar to the vowel in the first token followed by a portion similar to that in the last.

7. Advanced tongue root

There are fashions in the descriptions of vowels, resulting in some of the terms in Table VII being more discussed at certain times than others. This is particularly true of the way in which gestures involving the root of the tongue has been described. For the last decade or so, the most discussed of the minor vowel features

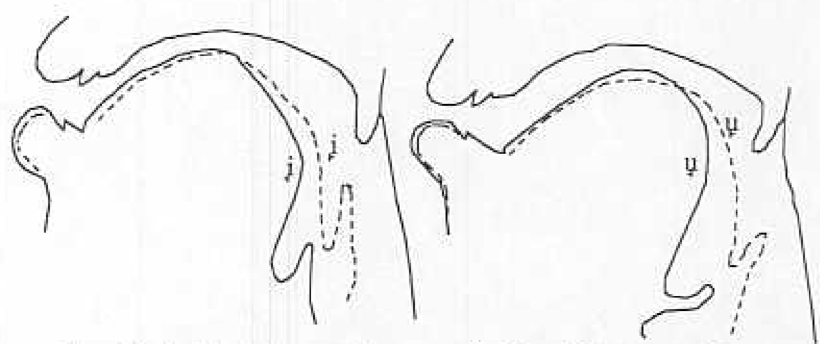


Figure 11. Tracings from x-ray cinematography films of Igbo vowels. [i̘] as in /ọ̄bì̘/ (ōbì in the standard Igbo orthography) "heart"; [i̙] as in /ù̙bi̙/ (ùbi) "poverty of ability"; [u̘] as in /i̘bú̘/ (ibú) "weight"; and [u̙] as in /ọ̄bu̙/ (ōbụ) "it is". In accordance with current IPA usage [̘] and [̙] are used to indicate Advanced and Retracted Tongue Root, respectively.

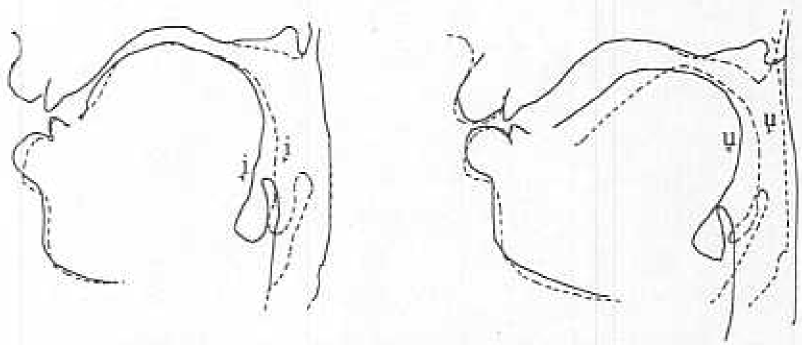


Figure 12. Tracings from x-ray cinematography films of Akan vowels based on Lindau (1979).

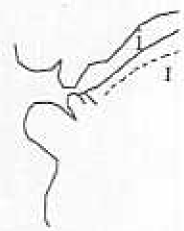
has probably been ATR (advanced tongue root). For many years before that it was probably "tense–lax"; and earlier still, at the end of the last century, terms such as "narrow–wide" and "primary–wide" were used. There is some overlap in the usage of each of these terms. We will begin by considering sets of vowels that can be said to differ in ATR; later we will compare these vowels with those that are said to be "tense" as opposed to "lax".

Many West African languages have vowels that differ in the position of the tongue root (Ladefoged, 1964). This difference is often most obvious in the case of high vowels. Tracings of the vocal tract shape in Igbo high vowels as shown by x-ray cinematography are given in Fig. 11. In each of these pairs the height of the tongue is very much the same. This is true irrespective of which of the two classic measures of tongue height is used, the location of the highest point of the tongue, or the height of the tongue body as a whole. Clearly, the most striking difference is that the root of the tongue is more retracted in the one case than in the other.

Another language in which there are two sets of vowels differing in ATR is Akan. Diagrams of the vocal tract shape (redrawn from data in Lindau, 1979) are shown in Fig. 12. As Lindau has pointed out, in this language (and probably in most languages in which ATR distinguishes two sets of vowels), the difference is not simply in the tongue root gesture, but in the enlargement of the whole pharyngeal cavity, partly by the movement of the tongue root, but also by the lowering of the larynx. Lindau suggests that the term Expanded is the most appropriate name for this feature. The lowering of the larynx sometimes results in these vowels having a slightly breathy quality; but in most cases that we have heard, the West African languages using this feature do not add markedly different voice qualities.

8. Tense–lax and ATR

The Akan vowels in Fig. 12 also differ in the height of the tongue in the front part of the oral cavity. This leads us to consider whether the differences between [+ATR] and [−ATR] vowels are the same as the differences between so-called tense and lax vowels, which may also differ in both the height of the tongue and the position of the root of the tongue. There are differences of this kind in Germanic languages, as exemplified by pairs of English words such as *heed–hid* and *bait–bet.*



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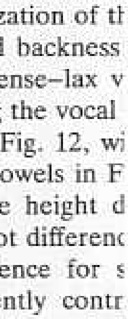

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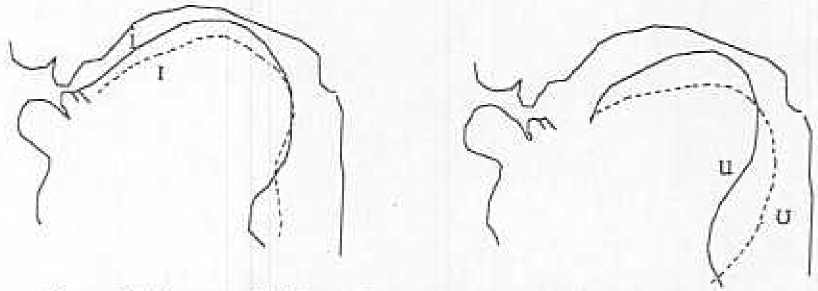

Figure 13. Some so-called Tense/Lax pairs of vowels in English (redrawn from data in Perkell, 1969).

Following Jones (1956) and a long British tradition, we regard the members of these pairs of vowels as being distinguished by variations of the major vowel qualities, Height and Backness (and perhaps Rounding). We note, of course, that the differences may involve diphthongization implemented through variation in height and the members of each pair also differ in length. But we do not find it necessary to consider any additional parameters such as tenseness.

We recognize, however, that there is also a long tradition in which these vowels are considered as being distinguished by the feature Tense (e.g. by Bloch & Trager, 1942, and by Chomsky & Halle, 1968). This leads us to consider two related questions that might be asked at this point. First, are we correct in our phonetic characterization of these vowels as differing only in the regular vowel dimensions of height and backness (and rounding), plus length? Second, are ATR variations the same as tense–lax variations? We can get a partial answer to these questions by comparing the vocal tract shapes shown for the Igbo vowels in Fig. 11 and the Akan vowels in Fig. 12, with the pairs of English vowels shown in Fig. 13 or the pairs of German vowels in Fig. 14. It may be seen that in each of the Germanic languages the tongue height differences within each pair of words are correlated with the tongue root differences in the same pair of words. In other words, there is no *prima facie* evidence for saying that tongue height and tongue root advancement are independently controlled parameters in Germanic languages. This conclusion is supported by statistical analyses of tongue shapes, in which it has been shown that the position of the tongue in sets of English vowels containing the tense–lax pairs

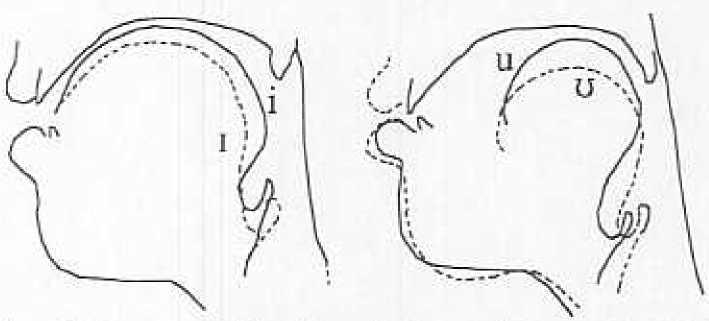

Figure 14. Some so-called Tense/Lax pairs of vowels in German (after Bolla and Valaczkai, 1986).

can be specified very completely by reference to only two variables (Harshman, Ladefoged and Goldstein, 1977; Ladefoged & Harshman, 1979). Using similar techniques, Jackson (1988) has also substantiated the finding that in English there does not appear to be a separate control of the root of the tongue; but he did find that there were three independent parameters of tongue shape in Akan. Accordingly it seems that the situation in English (and other Germanic languages) is not the same as that in West African languages. Although there may be some increase in

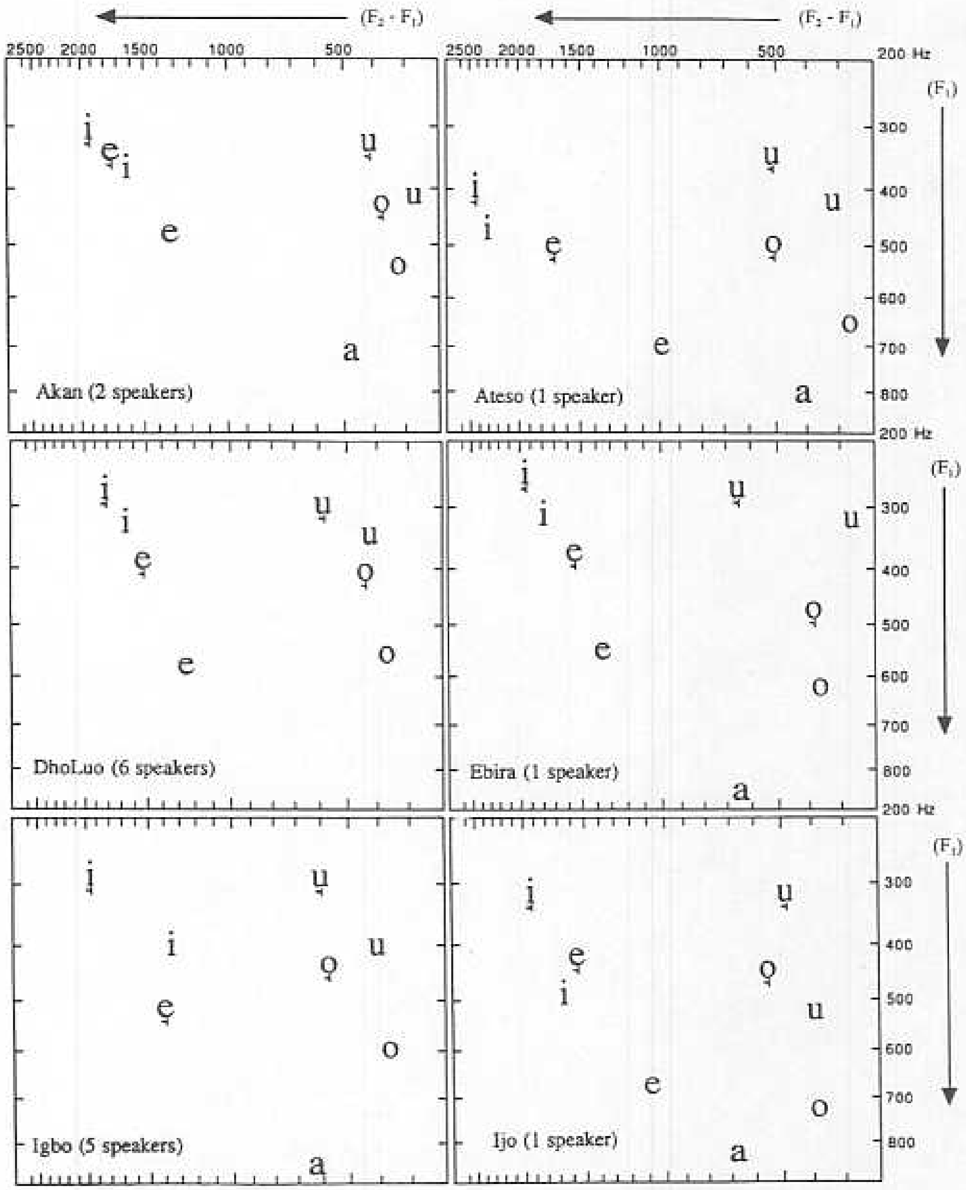

Figure 15. The acoustic effects of ATR in a number of languages. Vowels that are [+ATR] are indicated by a subscript [̣].

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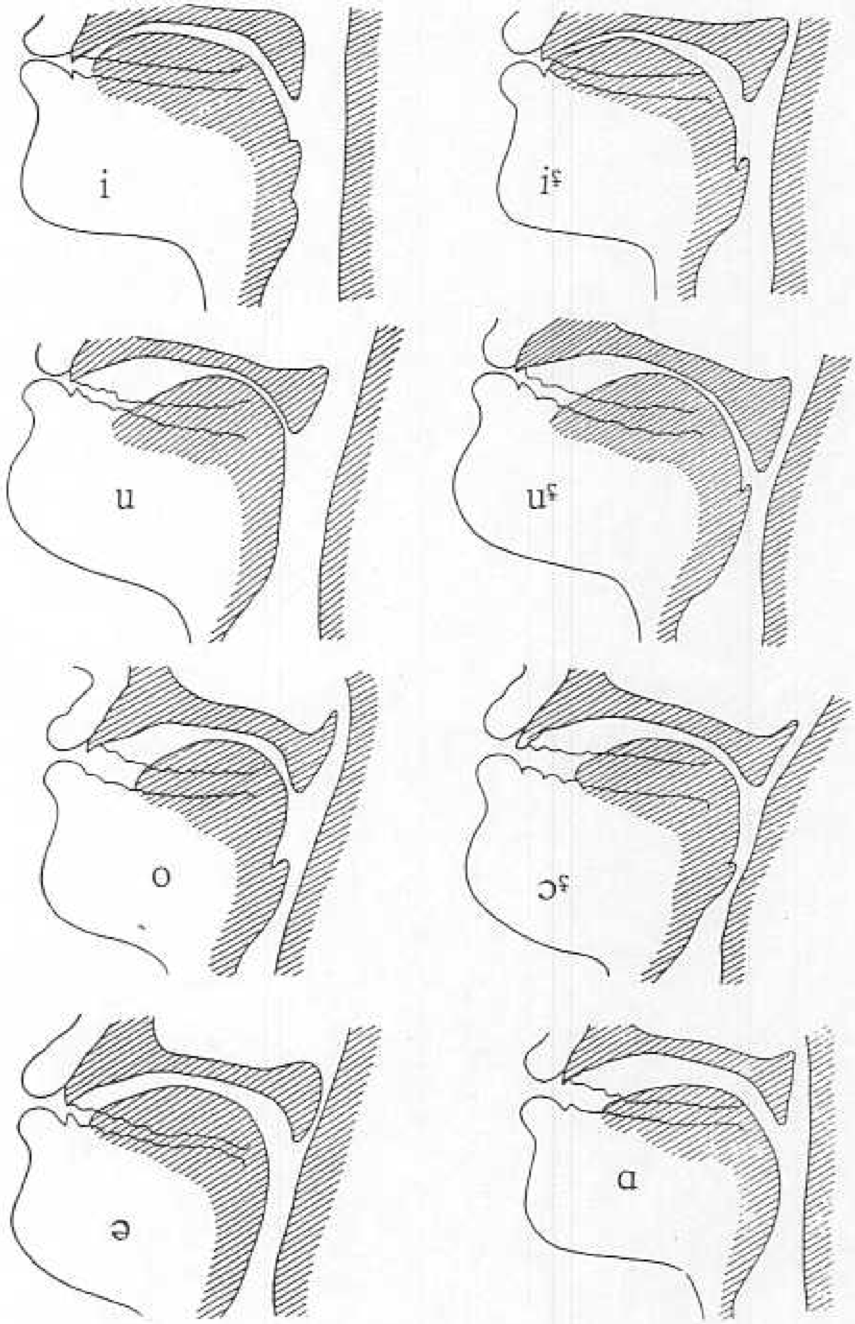

Figure 16. Pharyngealized vowels in Even (after Novikova, 1960).

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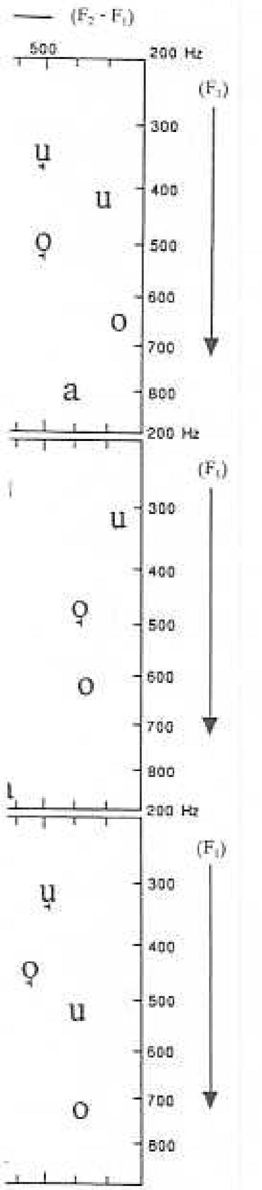


the height of the tongue accompanying the advancement of the tongue in Akan, the changes in tongue height are small in comparison with the expansion that occurs in the pharyngeal region. Furthermore, on some occasions there may be virtually no increase in tongue height for [+ATR] vowels, as is shown in the case of the Igbo vowels in Fig. 11. We conclude that the advancement of the tongue root is a separable tongue gesture in languages such as Igbo and Akan. In Germanic languages, however, it is simply one of the concomitants of vowel height.

If the advancement of the tongue root is an independent gesture that can be learned as part of the sound pattern of a language, then it must have observable acoustic consequences that distinguish it from all other possible ways of achieving the same acoustic effects. Lindau (1979) has also pointed out that there are differences between ATR and tense–lax characterizations of vowels in the acoustic domain. Figure 15 shows the acoustic characteristics of ATR differences in a number of languages. The Akan data are from Lindau (1979), the DhoLuo from Jacobson (1978), and the remaining languages are from our own files. It may be seen that in virtually all cases the [+ATR] vowel appears, in the traditional terms, to be raised and advanced. The only exception is the Ebira lower mid back vowel which is raised, but only very slightly advanced. Among front vowels, pairs of vowels differing in ATR have formant frequency characteristics that are reminiscent of so-called tense–lax pairs of vowels in Germanic languages, such as English *bead–bid*; *bade–bed*; both retracted tongue root vowels and the lax vowels are lowered and more central in the acoustic space. Among front vowels there is this parallel between [+ATR] and [−ATR] tongue root vowels on the one hand, and tense and lax vowels on the other, but among back vowel pairs there is no such parallel. The high back retracted tongue root vowel is always further back, rather than further forward, as is the case for the traditional lax back vowels. Lax vowels of all kinds are normally taken to be more centralized. Retracted tongue root vowels do not always have this characteristic.

9. Pharyngealized vowels

Another gesture of the tongue root involves its active retraction rather than advancement. This gesture takes several different forms, resulting in vowels that are variously called pharyngealized, epiglottalized, or strident. Among the languages which have been described as having pharyngealized vowels is Even, a Tungus language of North–Central Siberia (Novikova, 1960). This language has two sets of vowels as exemplified by the words in Table IX. The vowels in the set labeled pharyngealized all have a narrower pharyngeal passage and a raised larynx. Tracings of x-rays of the vocal tract shape in these vowels are shown in Fig. 16. (As drawn in

TABLE IX. Pharyngealized vowels in Even, a Tungus language of North-Central Siberia (Novikova, 1960)

Plain		Pharyngealized	
isli	*plucked*	iˤsliˤ	*reached*
us	*weapons*	uˤs	*guilt*
oj	*summit*	ɔˤj	*clothing*
əkən	*older sister*	ɑkɑn	*older brother*

Table X. Additional vowel properties in !Xóõ (see text for an explanation of the phonetic notation)

Plain	‖áa	*camelthorn tree*
Pharyngealized	qáˤa	*long ago*
Strident	!á̰o	*base*
Murmured	|a̤o	*slope*

part of the tongue below the uvula. This results in the vocal tract having three cavities rather than just the usual front and back cavities produced by a single constriction. As Catford (1988) has noted, a similar vocal tract configuration also occurs in some American English rhotic vowels, which like the Caucasian vowels, also have a low F_3.

In the Khoisan languages with pharyngealized vowels, only the back vowels /a, o, u/ have pharyngealized counterparts; but in these languages there are also additional contrasts among vowels (which we will discuss later), as shown for the vowel [a] in Table X. Traill (1985) has given good descriptions of all these sounds. Figure 18 is based on tracings from his cine-radiology film of a speaker of !Xóõ, showing [aˤ] and [uˤ] ([a̰] and [ṵ] in his transcription; we follow IPA practice in using [ˤ] for pharyngealization, keeping the subscript tilde for indicating creaky voice). The tongue positions for the plain back vowels [a, u] are also shown. It may be seen that there are considerable overall differences between the tongue shapes of the pharyngealized and non-pharyngealized members of each pair, very noticeably so in the case of the high vowel [u]. In fact, as Traill notes, on the basis of the tongue shape alone it would be difficult to regard [uˤ] as being in any sense a high back vowel; the reasons for symbolizing it in this way are largely auditory and phonological.

The auditory and acoustic effects of pharyngealization in !Xóõ do not seem to be the same as in the two Caucasian languages. We have heard recordings of all these languages, and have ourselves worked with speakers of !Xóõ and other Khoisan languages. Figure 19 shows spectrograms of the word [qaˤa] as pronounced by six speakers of !Xóõ. This word is especially interesting because it contains two vowels that are the same except for the pharyngealization that occurs on the first. The acoustic effects of pharyngealization are observable in only the first part of the word. The lowering of the third formant is similar to that reported in the Caucasian languages; but in the Khoisan examples, there is also a considerable *raising* of the lower formants, accompanied by a diminution of the energy around 400–700 Hz.

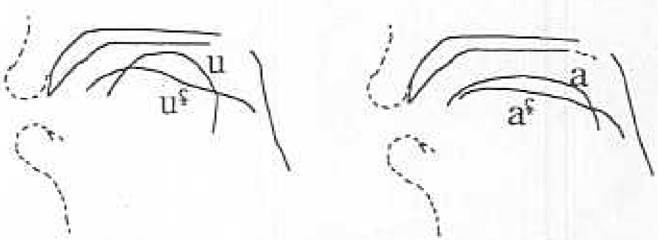
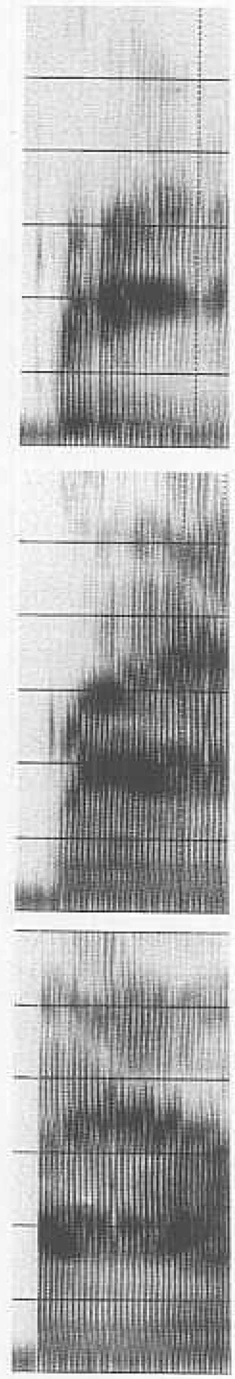


Figure 18. Plain and pharyngealized vowels in !Xóõ (after Traill, 1985).



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the originals these tracings imply that all these vowels are nasalized. That seems unlikely, and we do not know what to make of it. Obviously, we should be cautious in fully accepting the validity of the rest of the indicated vocal tract shape.) There is considerable similarity between these pairs of vowels and those we have been discussing in Akan. Furthermore, it is interesting to note that the two sets of vowels in Even also constitute vowel harmony sets in much the same way as the two sets in Akan: roots must contain vowels that are all of one set or the other.

Despite these similarities, both the examination of the x-ray tracings and Novikova's comments on the acoustic characteristics of these vowels suggest that there is a greater degree of pharyngeal narrowing in Even than in Akan. We will therefore consider these vowels to be characterized by pharyngealization rather than by ATR. Vowels with even more retraction of the tongue root occur primarily in two language families: Caucasian and Khoisan. In Caucasian languages such as Tsakhur and Udi each of the five vowels /i, e, a, o, u/ has a pharyngealized counterpart (Catford, unpublished). Tsakhur also has a sixth vowel, which Catford symbolizes /ɤ/, that has a pharyngealized counterpart (and Udi has three other vowels that do not have such counterparts). Catford reports formant frequencies for all these vowels. The most noticeable point in the acoustic structure is that the frequency of the third formant is markedly lower in the pharyngealized vowels. The frequency of the first formant is also somewhat higher.

X-rays of Tsakhur and Udi pharyngealized vowels are shown in Fig. 17. In addition Gaprindašvili (1966) has published some x-rays of pharyngealized vowels in two different dialects of Dargi. These all show that there is considerable narrowing in the pharynx near the tip of the epiglottis. What is equally interesting is that the whole front part of the tongue is bunched up, with a pronounced hollowing of the

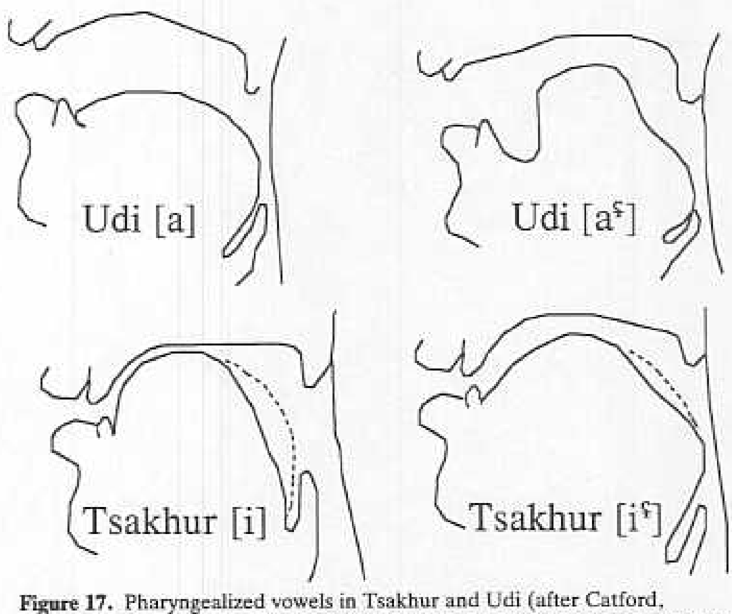
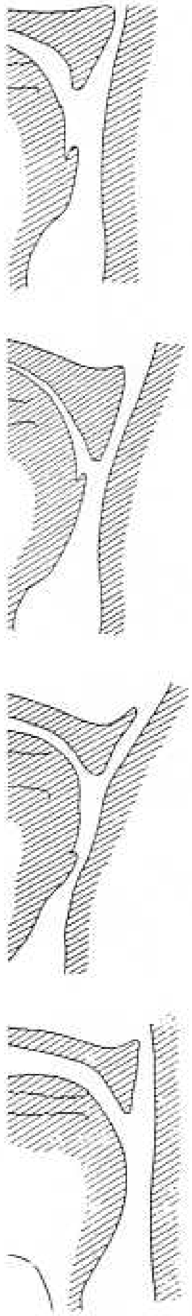


Figure 17. Pharyngealized vowels in Tsakhur and Udi (after Catford, unpublished, and Džejranišvili, 1959). The original sources are not completely explicit, but the dashed lines presumably represent raised portions of the sides of the tongue.



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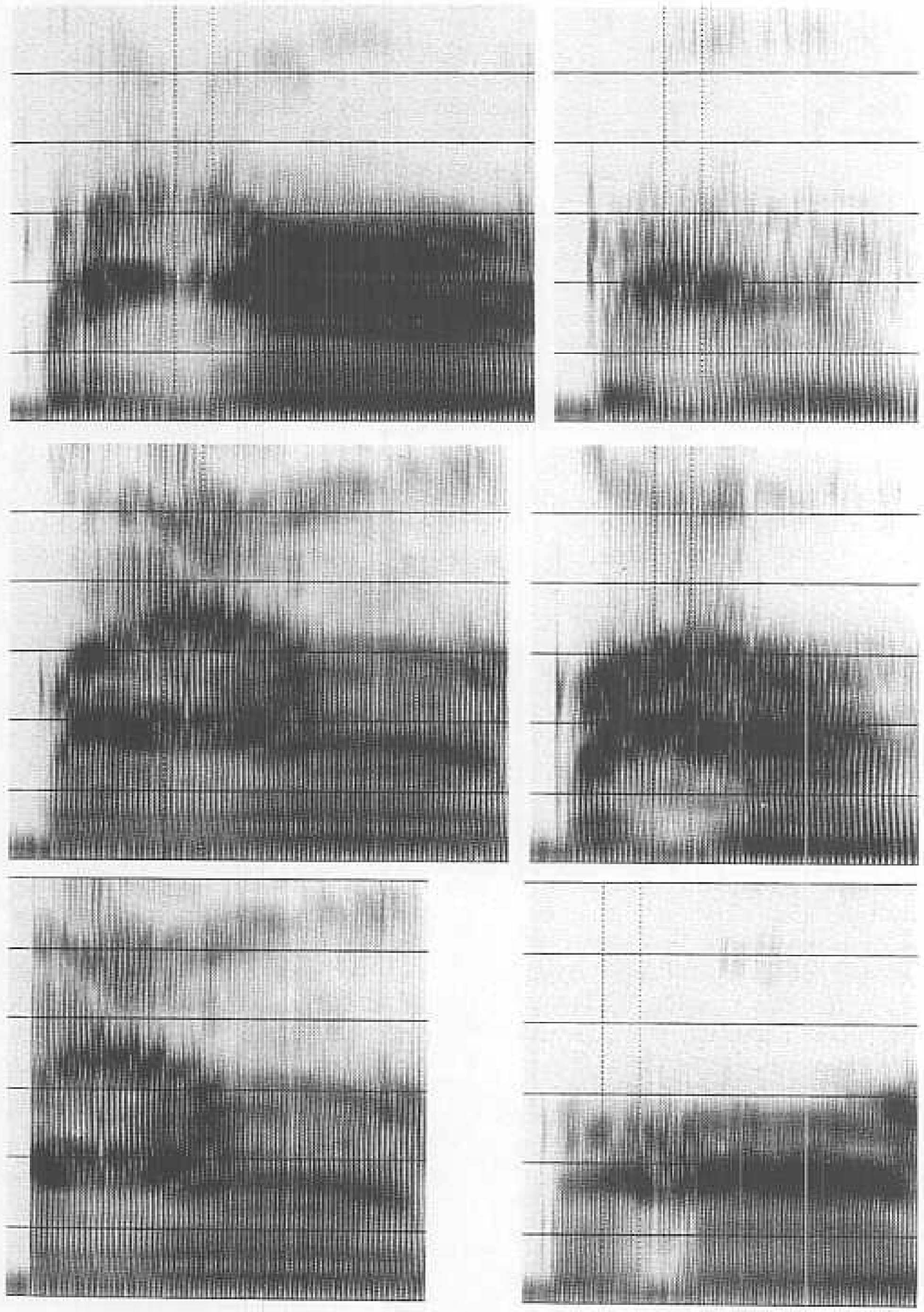


Figure 19. Spectrograms of the word [qáˤa] as pronounced by six speakers of !Xóõ, showing a pharyngealized vowel, followed by a non-pharyngealized vowel. The grid lines are at 500 Hz intervals.

10. Strident vowels

The Khoisan pharyngealized vowels that we have been discussing so far are not the so-called strident vowels of these languages. Traill (1985) suggests that the strident vowels may be regarded as pharyngealized breathy voiced vowels. He goes on, however, to emphasize that the vocal tract shape is not the same as in the pharyngealized vowels, and the laryngeal action is very different from that in breathy voiced vowels. It is clear that from a phonetic point of view strident vowels are best considered as involving a distinct articulatory mechanism of their own.

Traill (1985) has provided a great deal of valuable data on these vowels. Figure 20 shows, in addition to the plain and pharyngealized vowels discussed above, the strident vowels which, for want of better symbols, we will represent [a̳] and [u̳]. Traill, in accordance with his phonological analysis, transcribes them as [a̲h] and [u̲h]. It is clear that the whole body of the tongue is much lower for the strident vowels. In addition the back wall of the pharnyx, which is shown by the dashed line, is drawn forward, and "the epiglottis vibrates rapidly during these sounds" (Traill, 1985).

These vowels also have a constriction between the part of the tongue below the epiglottis and the tips of the arytenoid cartilages in the upper part of the larynx. A constriction of this kind does not occur in the pharyngealized vowels of !Xóõ or other Khoisan languages, and is also not apparent in any of the data that we have seen showing the pharyngealized vowels in Caucasian languages. It results in these vowels having a specific phonation type. Traill (1985) notes that "the arytenoid cartilages vibrate vigorously". He also notes, however, that the vocal cords themselves do not vibrate during this tight constriction in the upper part of the larynx. This whole shape in which the vocal cords are stiff and comparatively close together, is certainly not at all like that normally associated with what is called murmur or breathy voice. Figure 21 provides acoustic data from our own field recordings of strident vowels produced by six speakers. The first of these speakers is the subject Traill used for producing the data in Fig. 18 and Fig. 20.

These data support Traill's description. They show that there are irregular, noisy vibrations that might well have been produced by the approximated arytenoid cartilages and/or the epiglottis, rather than by the vocal cords themselves. The spectrograms show even more upward movement of the first and second formants than in the pharyngealized vowels we discussed in the previous section. Again the third formant generally moves downward.

We have discussed ATR, pharyngealized and strident vowels as if they were

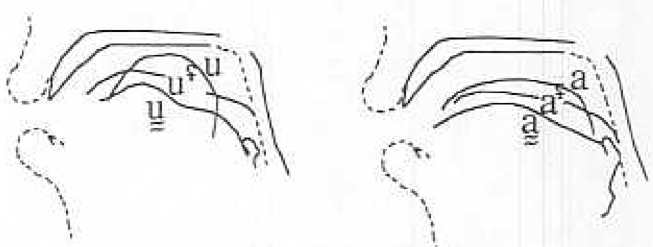
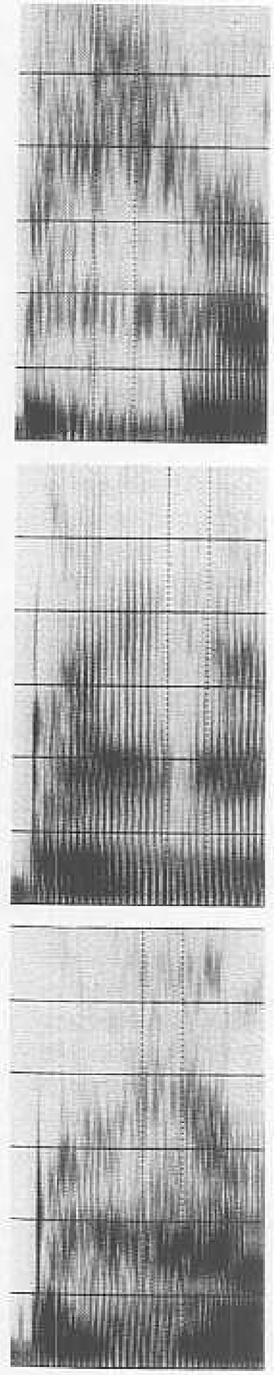


Figure 20. Plain, pharyngealized and strident vowels in !Xóõ, based on data in Traill (1985).



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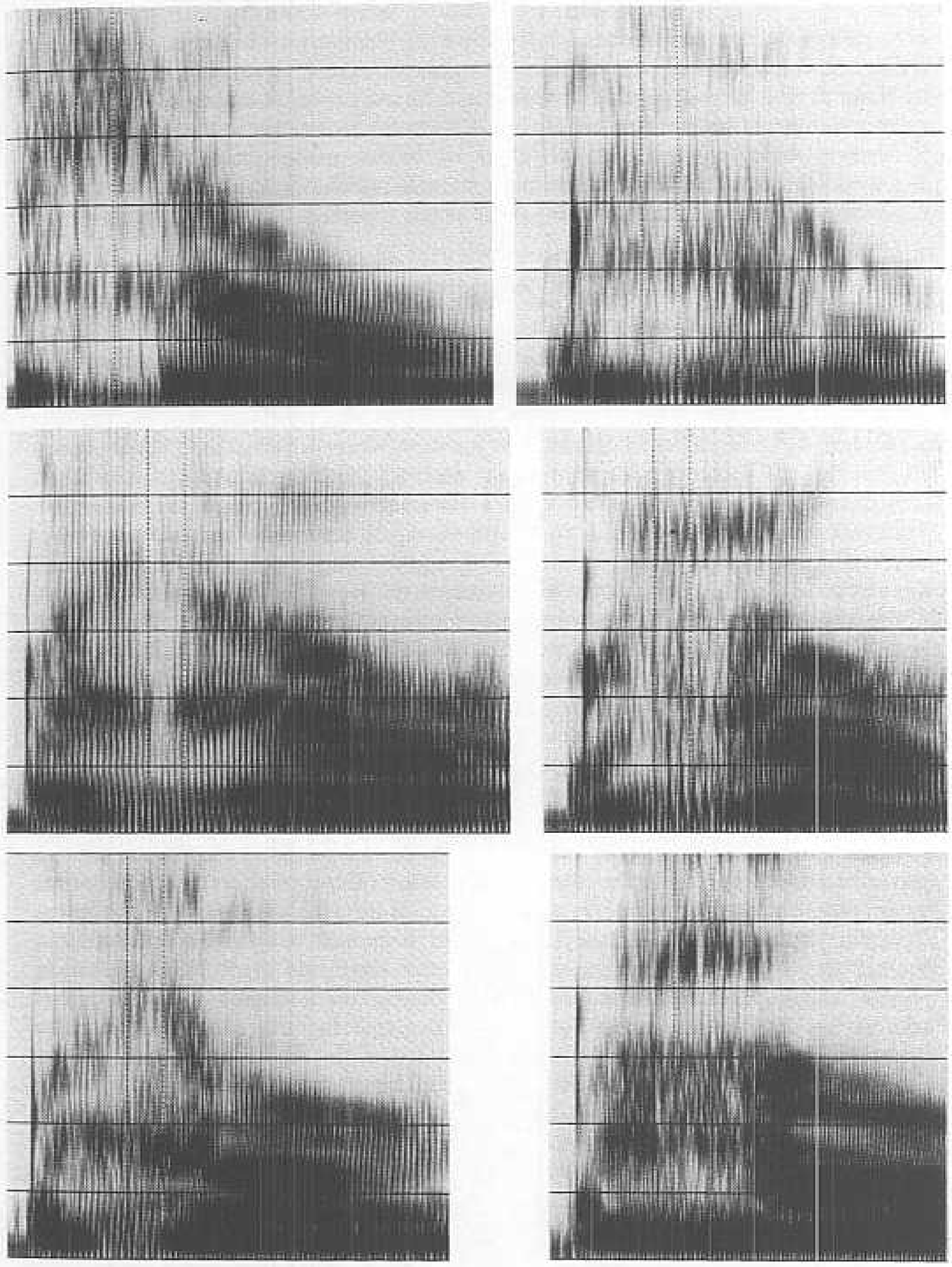

Figure 21. Spectrograms of the pronunciation of the word ! ȁo containing the low back strident vowel, spoken by six speakers of !Xóõ. The grid lines are at 500 Hz intervals.

characterized by separate properties. However, as we noted, [−ATR] vowels are very much akin to pharyngealized vowels, and strident vowels might be regarded as a more extreme form of pharyngealized vowels. All these vowels are characterized by some degree of pharyngeal narrowing and larynx raising. Languages seldom use more than one of the three possibilities. We cannot reduce these three possibilities to a single binary contrast because of the contrastive use of plain, pharyngealized and strident vowels in !Xóõ. But the most suitable phonological parameters to use in describing these vowels are not clear to us at this moment.

11. Rhotic vowels

As we mentioned above there is yet another class of vowels in which the root of the tongue is often retracted, namely the rhotic (r-colored) vowels. These sounds are very unusual, and occur in less than one percent of the world's languages (Maddieson, 1984). They are, however, comparatively well known, in that they occur both in some forms of English, and in some forms of Chinese. The common attribute of all rhotic vowels is in their acoustic structure, rather than in their articulation. Rhotic vowels always have a lowered frequency of the third formant. Sometimes these sounds are produced with the tip of the tongue up, and sometimes with it down; often the tongue is bunched up in the anterior-posterior direction; and there is usually a narrowing of the vocal tract in the region of the epiglottis.

The rhotic vowel that occurs in many American English pronunciations of the vowel [ɚ] as in "bird" has been well described. In a recent study, Lindau (1985) shows the vocal tract shapes that occur in the pronunciation of six American English speakers, as observed by x-ray cinematography of the phrase "Say bird again". It is clear that there is generally a bunching of the tongue body in the anterior-posterior dimension, and, often, a narrowing of the vocal tract in the vicinity of the epiglottis. This vowel is one of the very few sounds in the world's languages in which the required acoustic structure can be made with some very different articulatory gestures. Uldall (1958) has shown that the tip of the tongue can be up or down. This may produce differences in the relative amplitude of the formants (to which the ear is not very sensitive) but virtually no difference in the frequencies of the first three formants. To demonstrate this, Uldall, who is herself a speaker of American English, produced two different versions of the vowel in "bird", thus making it possible to compare the articulations without having the additional complication of one having been pronounced by one speaker and the other by another. Her palatograms and spectrograms of the two types of [ɚ] show how two different articulations can produce strikingly similar acoustic results.

What may be a different kind of rhotacization has been reported by Emenau (1939) in Badaga, a Dravidian language. He suggests that in this language there are five vowels, /i, e, a, o, u/, each of which can be "normal, half-retroflexed, (or) fully retroflexed". The half-retroflex vowels are described as being "produced with the edges and tip of the tongue retroflexed or curved upward to approach the alveolar ridge, but without touching or causing friction at any point; the front of the blade of the tongue seems to be raised also in this manner of vowel production". His description of the full-retroflexed vowel is as follows: "In the vowels with fully-retroflexed resonance the whole tongue is strongly retracted, the edges are curved upwards towards the hard palate well behind the alveolar ridge but without touching or causing friction at any point, and a channel is left in the center of the tongue well visible at the tip in a V-formation". Emenau offers good evidence for all these $3 \times 5 = 15$ vowels being phonologically contrastive. We have not heard any speakers of Badaga ourselves, and so do not know if any other analysis is possible. For example, we do not know whether in the fully-retroflexed vowels the retroflex qualities are superimposed as additional vowel features, or whether they could be regarded as sequences of vowels followed by retroflex approximants.

12. Fricative vowels

The next added vowel feature to be discussed is frication. Fricative vowels can usually be thought of as syllabic fricatives that are allophones of vowels. The best known examples are the allophones of /i/ that occur after retroflex (apical postalveolar) and palatal fricatives and affricates respectively in Standard Chinese. These vowels are made with the tongue in essentially the same position as in the corresponding fricatives. Because of the articulation used in the retroflex case, these vowels have sometimes been referred to as "apical" vowels. This term is not appropriate for the palatal cases. In addition, in Liangshang Yi there are fricative vowels which are syllabic variants of a labial fricative (Maddieson & Hess, 1989) and in Czech a laminal /r/ can occur as a fricative vowel (Ladefoged, 1971). This seems to indicate that the more general term fricative vowel is preferable. In both Yi and Czech these vowels may be not only fricated but also trilled. In the case of the Yi labial vowel, it is the lips that are trilled.

13. Phonation types

We have discussed differences among vowels involving phonation types elsewhere (Ladefoged, Maddieson & Jackson, 1988), and accordingly will note here only the possibility of some phonological contrasts. Most languages use only the two different phonation types, voiced and voiceless; and these two types usually contrast only among consonants. For vowels, the status of phonological contrasts between voiced and voiceless possibilities is not always clear. They have been reported to have some phonological role in Ik (Heine, 1975) and Dafla (Ray, 1967). As a surface phonetic phenomenon they are an important areal feature of the Amerindian languages of the Plains and the Rockies. In some of these languages they appear to be phonologically contrastive. For example, Miller & Davis (1963) reconstruct voiceless vowels for Proto–Keresan. In other languages, such as Acoma (Miller, 1965), they are not underlying phonemes; in yet others, such as Comanche, their status is problematic (Armagost, 1986). Voiceless vowels also occur in the Bantu languages of the Congo basin and Indo-Iranian languages in the Indic/Iranian border region; but here they are simply surface phonetic phenomena. Voiceless vowels occur as allophones of regularly voiced vowels in many languages, including English (e.g. in the first syllables of "peculiar" and "particular"). In Japanese there is a contrast between the voiceless allophones of /i/ and /u/ between voiceless obstruents, as in [kjʃi] "shore" and [kɯ̥ʃi] "comb".

Many languages have phonemic contrasts involving other kinds of phonation. In order to describe these differences we need a framework for phonation types. Unfortunately there is no agreed set of terms that can be used. The most well known theories are those of Catford (1977*b*), Laver (1980) and Stevens (1988). Our views have been given in Ladefoged (1971, 1983) and elsewhere. Both Catford and Laver consider the complete range of voice qualities that humans can produce, including phonation types such as whisper and falsetto, neither of which is used to contrast lexical items in languages. If we were to use either of their descriptive systems we would overspecify the linguistic phonetic possibilities. Furthermore, although their descriptions are expressed largely in physiological terms, describing actions of the vocal cords, they themselves supply very little supporting physiological data. Instead they rely on the extensive published literature on the larynx. But in fact there have been almost no studies showing that even a small groups of subjects makes any *linguistic* use of the laryngeal actions postulated for the various glottal states they describe.

Stevens's work differs in two respects. First it is embodied in a quantitative model of the vocal cords. Second its main aim is to account for phonological contrasts in terms of distinctive features of the larynx. Stevens also does not produce any analytical data showing what groups of subjects do in forming contrasts. However, he argues persuasively on theoretical grounds that there are three distinct ways in which the glottis can vibrate, with minor variations possible within each of them. Our linguistic findings, to be reported below, agree with Stevens's claim.

Some languages exploit a breathy voice quality which some linguists call "murmur" (Ladefoged, 1971; Pandit, 1957), in which the vocal cords vibrate without coming completely together. Murmur is exemplified noncontrastively in English intervocalic [ɦ], as in "behind", and contrastively in many Indo–Aryan languages in the production of consonants. Gujarati has developed surface phonetic contrasts between plain and murmured vowels, in addition to the more common Indo–Aryan contrasts between plain and murmured stops, as shown in Table XI. !Xóõ contrasts involving murmur have already been illustrated in Table X.

Another type of vowel is produced with the body of the vocal cords, the vocalis muscle, stiffened, forming a laryngealized type of phonation. A good example occurs in Mpi, a Tibeo–Burman language with six tones, each of which may occur with a plain or a laryngealized vowel, so that the same articulatory sequence, /(si/, has 12 different meanings depending on accompanying tone and phonation type, as shown in Table XII.

Often the contrast is not so much between regular voicing and laryngealized voicing, but instead is between a slightly breathy and slightly laryngealized type of phonation. Parauk (Wa), a Mon–Khmer language, uses two such contrasting phonation types (Maddieson and Ladefoged, 1985). A more extreme type of laryngealization, creaky voice, occurs in some languages. We will regard this as a separate phonation type. Jalapa Mazatec, an Otomanguean language spoken in

TABLE XI. Contrasts between voiced and murmured vowels in Gujarati (for further comparison, contrasts between voiceless aspirated, murmured aspirated, voiceless, and voiced consonants are also shown)

	Voiced initial		Voiceless initial	
Plain vowel	bar	*twelve*	pɔr	*last year*
Breathy vowel	ba̤r	*outside*	pɔ̤r	*early morning*
Aspirated consonant	bʱar	*burden*	pʰɔdz	*army*

Table XII. Contrasting phonation types and tones occurring on the syllable /si/ in Mpi

	Plain	Laryngealized
1. Low contour	*to be putrid*	*to be dried up*
2. Low	*blood*	*seven*
3. Mid contour	*to roll*	*to smoke*
4. Mid	(a color)	(classifier)
5. High contour	*to die*	(man's name)
6. High	*four*	(man's name)

Mexico has a three-way contrast (at least on the surface) between creaky, breathy (murmured) and modal (plain) vowels (Kirk, Ladefoged & Ladefoged, 1984).

In summarizing the use of variations in phonation type to differentiate among vowels, we may note that there is a continuum going from a glottal state in which the vocal cords are in the voiceless position with the arytenoid cartilages far apart, to one involving a creaky voice with the arytenoid cartilages pressed firmly together. Most languages do not use any of these glottal states to distinguish among vowels. A number of languages use two, selecting various possibilities within the continuum. A few rare languages, such as Jalapa Mazatec, have three contrasts of this kind.

14. Dynamic variations among vowels

Numerous languages distinguish long and short vowels. Occasionally there are three contrasting vowel lengths, as has been shown by Lehiste (1970) for Estonian. Lehiste also comments on a claim by Hoogshagen (1959) that Mixe, a Mixe–Zoque language of Mexico, has three degrees of length, concluding that "vowel quantity in Mixe is segmental, i.e., does not depend on syllable structure or on word patterns as was the case in Estonian". Our reading of Hoogshagen's data lead to the same conclusions; Hoogshagen provides numerous examples, mainly monosyllabic words, showing that there are three degrees of contrastive vowel length, independent of the syllable pattern, the vowel quality, the preceding or following consonants, the stress, the pitch and the intonation. Examples are given in Table XIII.

In some languages there are long, or very long, vowels with no apparent syllable break within the sequence. It would be possible to treat these overlong vowels as sequences of short vowels; alternatively, we can distinguish up to four degrees of length, as has been done for the Bantu language Kamba by Whiteley & Muli (1962). Examples (from Ladefoged, 1971) are given in Table XIV.

Whiteley & Muli (1962) point out that the very long vowels have cognate forms in neighboring languages with an intervening consonant within the vowel sequence. Nevertheless, they consider them to be single very long vowels; there is no obvious reason to consider them as consisting of more than one syllable in Kamba.

Table XIII. Three contrastive vowel lengths in Mixe (data from Hoogshagen, 1959)

poʃ	*guava*	pet	*climb (n)*	piʃ	*flea*
poˑʃ	*spider*	peˑt	*broom*	piˑʃ	*marigold*
poːʃ	*knot*	peːt	*Peter*	tʃiːt	*cat*

TABLE XIV. Four degrees of vowel length in Kamba (from Ladefoged, 1971; cf. Whiteley and Muli, 1962)

kwelela	*measuring (patch)*	kʊʃa	*start off*
kweleˑla	*moving backwards and forwards*		
kueleːla	*aiming at*	kʊʃaː	*giving birth*
		kʊʃaːː	*giving birth frequently*

If we consider phonetic descriptions of vowels to be equivalent to statements about the targets of vocalic gestures, then we can consider diphthongs to be vowels that have two separate targets. There is a problem with this definition, in that it does not distinguish between diphthongs and long vowels, which may well be considered to be vowels that have two identical targets. Accordingly we must stipulate that diphthongs must have two different targets. As with all linking of targets, the time course of the movement from one target to the next has to be specified. We believe that languages may differ in the way that diphthong targets are joined, in that there may be a straight linear transition or a variety of controlled motor movements. Lindau, Norlin & Svantesson (1985) and Peeters & Barry (1989) have shown that there are language-specific differences in the movements within diphthongs.

The kinds of vowels that occur as targets in diphthongs are no different from those that occur as single vowels. Consequently, in this paper, in which our aim is to describe the set of phonologically contrastive sounds that occur in the languages of the world, there is little extra to be said about diphthongs. No new features are needed. Of course from a phonological point of view, diphthongs pose many interesting problems, such as why some sequences are preferred to others. But these are outside our present purview, and will have to await treatment in Maddieson's forthcoming survey of patterns of sequences of sounds.

15. Summary

Finally, we will compare our findings in this paper with those of the most comprehensive previous survey, that of Lindau (1978). We are largely in accord with respect to the major features Height and Backness, noting only that recent evidence has suggested that there may be as many as five distinctive vowel heights. Our differences on the third major feature, Rounding, are more in form than in substance. We regard rounding as a feature that dominates both Compression and Protrusion, a possibility that was not open to Lindau before the advent of hierarchical phonological structures, although she recognized the distinction between these two types of lip action. Among the additional vowel properties, nasalization is now slightly better understood, but remains as a binary feature. We have proposed a slightly larger set of tongue body features, rearranging Lindau's feature "expanded" to allow for distinctions in ATR, Pharyngealization and Stridency, in addition to Rhotacization, which both classificatory systems include; we have not, however, found it necessary to distinguish between peripheral and non-peripheral vowels as she did. In addition we have noted (without discussion in this paper) some additional distinctions among vowels involving phonation types and variations in dynamic properties.

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Department of Linguist
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