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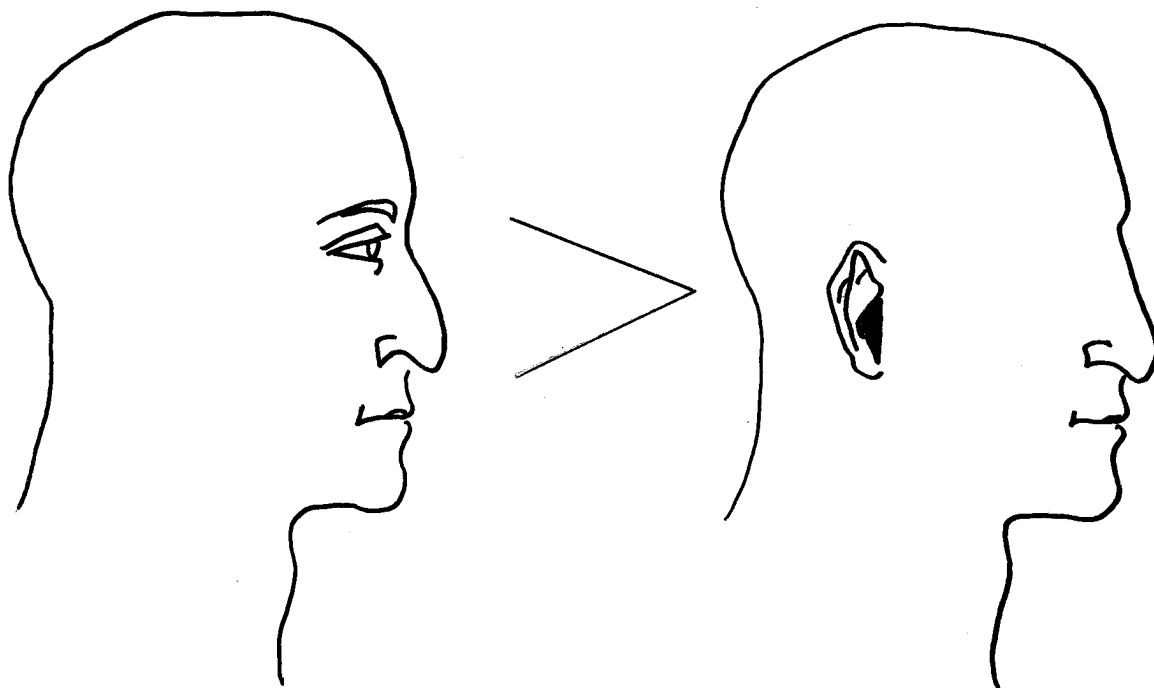
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"Ganii Yaa Fi Jii"



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Aspects of Hausa Tone

by

Laura Frances Meyers

UCLA Working Papers in Phonetics, 32
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For Martin and Chori

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ABSTRACT OF THE DISSERTATION°

Aspects of Hausa Tone

by

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Professor Paul M. Schachter, Chairman

Professor Peter Ladefoged, certifying member

Professor Thomas Penchoen, certifying member

This dissertation is an in-depth experimental investigation into the nature of Hausa tone and intonation. Throughout the dissertation all claims are supported by experimental phonetic data obtained through the use of a hardware pitch meter combined with a computer program which extracts fundamental frequency measurements for every 10 msec of the utterance. Oscillomink recordings are also used.

Chapter 1 consists of an investigation into segmental influence on pitch in Hausa, beginning with a review of the literature describing the segmental inventory of Hausa. Because of controversy among Hausa scholars about the exact nature of the consonantal inventory, the segments comprising the inventory to be used in this experiment are re-analyzed using oscillomink recordings and electroglottograph recordings, resulting in new descriptions of some Hausa segments. Next, the pitch effects of these consonants are systematically measured, the findings are reported and compared, and they are discussed in terms of probable perceptual salience.

In Chapter 2, phonological rules of pitch assignment are formalized to account for the pitch contours found for a large systematically elicited Hausa corpus. In particular it is found that: 1) sequences of like tones, either all high or all low, and sequences of like pitches are not realized at the same pitch, but have a downward contour; 2) in some cases, high tones following immediately preceding low tones are assigned the same pitch as the preceding low tone; 3) with a sequence of high-high-low, the second high tone is often raised to a higher pitch than the high tone preceding it. These three pitch patterns have not been described for Hausa before this study. Chapter 2 concludes with a discussion of whether extrinsic rule ordering is required for the rules formalized in this chapter.

Chapter 3 consists of a very incomplete overview of the interaction of syntax and semantics and pitch in Hausa in the form of suggestions for further research. Major constituent breaks are not found to be marked by any unusual pitch perturbations.

Interrogatives, including both yes-no questions and question-word questions, are found to have pitch patterns which differ from previous accounts, especially in that the interrogative pitch raising is found to extend to more of the utterance than had previously been supposed. The pitch patterns of utterances containing the identifier particle nee/cee are analyzed, and it is demonstrated that although this particle is underlyingly polar in tone, it undergoes the pitch assignment rules formalized in Chapter 2. Finally, utterances containing some lexical items which might be expected to perturb pitch are analyzed. The pitch patterns of utterances containing the modal operators sai 'only, until', har 'even, until', and koo 'or, even, question, if' are investigated. It is found that these modal operators initiate a new downdrift pattern only if they interrupt the scope of another modal such as factive or negative. The conjunction ammaa 'but' is also considered, and it is found that in the data analyzed here it always starts a new intonation pattern; this suggests that perhaps this word always begins a new sentence in Hausa. Two exclamations, kai 'wow!' and ashee 'boy!' are shown to have the most extreme pitch realizations of all the lexical items analyzed. No formalization of any of the findings in Chapter 3 is attempted because it is felt that the data are too limited to warrant incorporation of these tentative generalizations into the grammar.

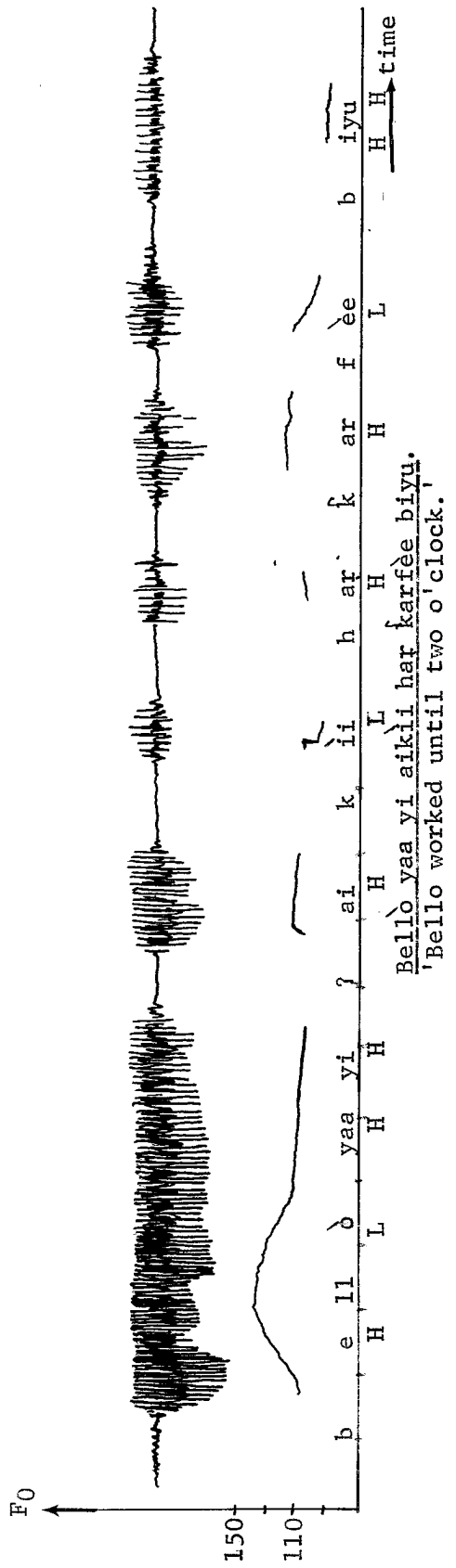


Figure 0.1: Wave form and pitch curve of a Hausa utterance demonstrating how actual pitch realization differs from what would be predicted from claims made in the literature.

To this end, two much less modest projects were begun. First, a study of consonantal effects on pitch was undertaken. Immediately this ran into problems, because the experimental recordings showed that the consonantal inventory differed from the traditional descriptions. This required a detailed investigation into the consonantal inventory. Using this newly described inventory, a study of the pitch effects of segments was done. This is presented as Chapter 1. Next, the generalizations, in the form of phonological rules of pitch assignment, which resulted in the unexpected pitch realizations of lexical tones, were extracted from a large amount of data gathered to test various hypotheses. These rules were formalized and at least a partial grammar of pitch assignment is presented in Chapter 2. By this time the study had lengthened both in scope and time, and, as a result, the original task of describing the interaction of pitch and syntax and semantics, if exhaustively and properly approached, seemed too exhausting. Therefore, in Chapter 3, a very incomplete overview of some correlations between syntax and semantics and pitch perturbations is given in the form of suggestions for further research.

Throughout this investigation the author has been reminded countless times that adequate descriptions of the sound patterns of a language must be based on experimental evidence if correct descriptions and, yes, even explanations, are to be arrived at. Knowledge of the language quite often results in the listener 'hearing' pitch patterns which are not present in the physical signal. Yet, the actual physical signal is predictive of possible future change in the language, and the synchronic rules of the grammar may refer to the actual pitch not the underlying tone. The Hausas have a proverb that sums it all up:

"Ganii yaa fi jii."
'Seeing is better than hearing.'

CHAPTER 1

In the introduction it was shown that the pitch contours for Hausa sentences with downdrift were not what would be predicted by any previous study of Hausa tone. Perturbations of the expected pitch patterns resulted from segmental influence, the application of phonological rules, and the interaction of syntax and semantics with the rules for pitch assignment. In this chapter I discuss the relationship between segments and the realization of pitch, with emphasis on the predictable perturbations which certain consonant types have on the realization of pitch within the following syllable. In the first section, 1.1, I will discuss the phonetic bases for a correlation between segment types and pitch. In the second section of the chapter, 1.2, I will present and discuss the universal hierarchy of segment types proposed by Hyman and Schuh (1974), by which they predict segmental influence on tone. Their study is based on the interconnection between segments and pitch in phonological rules in a large number of languages rather than on experimental phonetic evidence. In the third section of this chapter, 1.3, an examination of the phonetic properties of Hausa segments will be presented. The section will include a review of the literature on Hausa segments, plus some new experimental evidence that shows that some of the segments have different phonetic properties than what has been traditionally claimed. In the fourth section of this chapter, 1.4, I will discuss whether the segments of Hausa have the effects on pitch which would be predicted by the hypotheses which were discussed in Sections 1.1 and 1.2. Three additional questions will be discussed. First, how significant are these segmental perturbations from the standpoint of perception? Second, from my findings about the correlation of pitch and segments in Hausa can predictions be made about the direction of historical change? Would the consonantal effects lead to the development of additional tones, or, conversely, would the effect of pitch on consonants lead to a change in the inventory of consonantal segments in Hausa? Third, do my findings predict the development of phonological rules for pitch which are contextually governed by the features of preceding segments?

1.1 The Phonetic Interrelationships Between Segments and Pitch

Pitch is determined by the rate of vibrations of the vocal cords -- the higher the rate of vibration, that is, the greater the number of vibrations per second, the higher the fundamental frequency, or pitch. The rate of vibration of the vocal cords is influenced by a complex of interrelated factors, including the rate of air flow through the glottis and across the vocal cords, the tension of the vocal cords, and the state of the vocal cords during different phonation types. In addition, the height of the larynx can often be correlated with the rate of vibration of the vocal cords, but, at this

time, it is not clear whether this is because raising the larynx increases the *tension* on the vocal cords, or because it decreases the *mass* of the vibrating part of the vocal cords, or both. While the main gestures required for adjustment of pitch involve varying the tension of the vocal cords by stretching or slackening them, *segmental* influence on pitch is usually the result of changes of air flow associated with states of the vocal cords during different phonation types, and to a certain extent, the height of the larynx. Ohala (1973) discusses how these variables determine the pitch of a segment. With reference to changes in air flow, Ohala claims that although there is an increase in subglottal air pressure during stressed syllables, the experimental evidence to date shows that "the extent to which pitch is actively regulated by variations of the expiratory force is negligible" (1973, p. 6). There are, however, *passive* regulations of the air flow that occur during the articulations of various consonant types, especially obstruents, and during certain phonation types such as creaky and breathy voice, which do result in pitch changes. These passive regulations of air flow will be discussed in detail below. With reference to changes in the tension and state of the vocal cords, Ohala points out that the pitch of a segment can be varied by active adjustment of vocal cord tension by the muscles attached to the larynx and the adductor muscles of the larynx. The strap muscles, by adjusting larynx height, also are involved in the raising and lowering of pitch. At this time, as he suggests, the experimental evidence does not support a correlation between the small displacements of the larynx associated with certain segment types such as voiced and voiceless obstruents and the changes in pitch which are predicted for these segment types. The variations in pitch which do result from the raising or lowering of the larynx usually are associated with intonation contours and the tonal contours found in tone languages. Another factor mentioned by Ohala which may influence fundamental frequency is added *tension* on the vocal cords caused by the heightened position of the tongue in the articulation of high vowels and palatal and velar consonants. High vowels, along with palatal and velar consonants, are articulated with a high tongue position; this causes a slight upward pull on the larynx which increases the tension on the vocal cords. (p. 6).

It was suggested by Halle and Stevens (1971) that segment types and pitch are interrelated because during voiced obstruents the vocal cords are slack, and this would lower pitch, and during voiceless obstruents the vocal cords are stiff, and this would raise pitch. However, Ohala points out that there is no experimental evidence supporting their claim and that electromyographic recordings of laryngeal muscular activity "revealed no obvious difference in the tension of the laryngeal muscles during the production of the voiced/voiceless distinction...other than what would be expected for the abduction of the cords during voiceless obstruents" (1973, p.7). Ohala also points out that Halle and Steven's hypothesis predicts that obstruents would have pitch raising or lowering effects on the preceding as well as the following vowel. Experimental evidence, including

the data obtained for this research, shows that pitch usually falls before both voiced and voiceless obstruents.

It seems that the major interactions of the segment types and pitch involve (1) variations in pressure across the vocal cords and hence in the air flow through the glottis caused by variations in the state of the vocal cords during the articulation of various consonant types (the higher the rate of air flow, the higher the pitch), and (2) variations in vocal cord tension caused by the muscles attached to the larynx -- the main way of adjusting for pitch (the longer the vocal cords the higher the pitch). In a tone language, such as Hausa, where each syllable has lexical tone, there is a constant interaction between gestures for pitch and gestures for articulation of segment types. The gestures for phonation types may affect pitch by affecting the tension on the vocal cords, and the rate of air flow. Conversely, the gestures for pitch may influence the realization of segments by affecting vocal cord tension. Figure 1.1 is a diagram adapted from Ladefoged (1972) which shows how the gestures for pitch and the gestures for glottal stricture, which determines phonation type, differ.

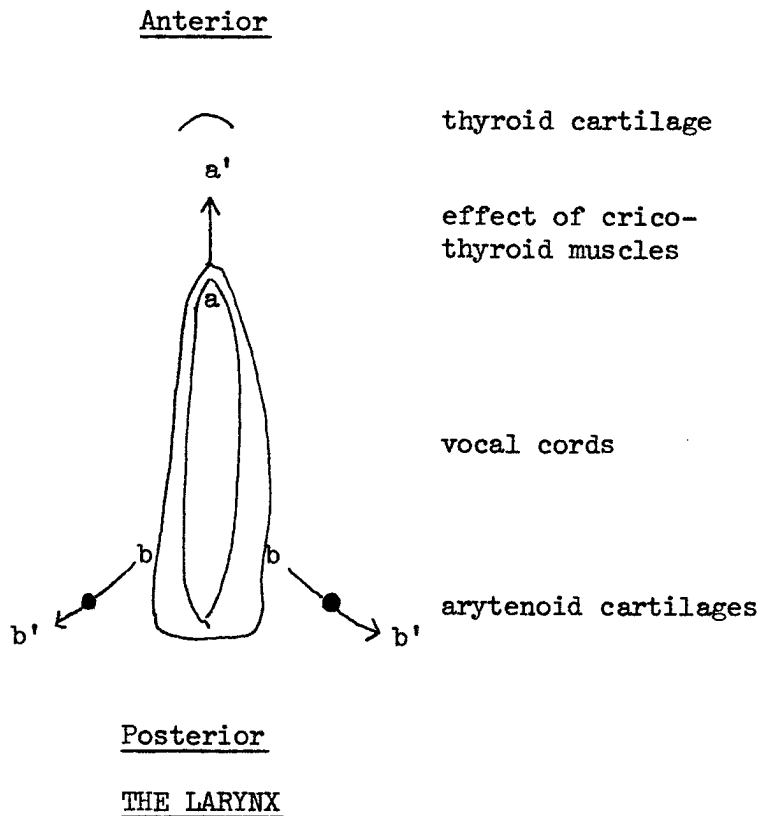


Figure 1.1: Gestures involved in pitch and phonation.

The gestures required for adjustment of pitch involve movement along the anterior-posterior dimensions, $a \rightarrow a'$. The contraction of the cricothyroid muscles moves the thyroid cartilage forward, causing the vocal cords to be stretched towards the front of the throat. This increase in length results in an increase in fundamental frequency, that is, it raises pitch. Differences in phonation types are caused by movements along the $b \rightarrow b'$ dimensions, which is achieved through the movement of the arytenoid cartilages. Figure 1.2, also adapted from Ladefoged (1972, p. 75), shows schematic representations of the state of the glottis during four different phonation types.

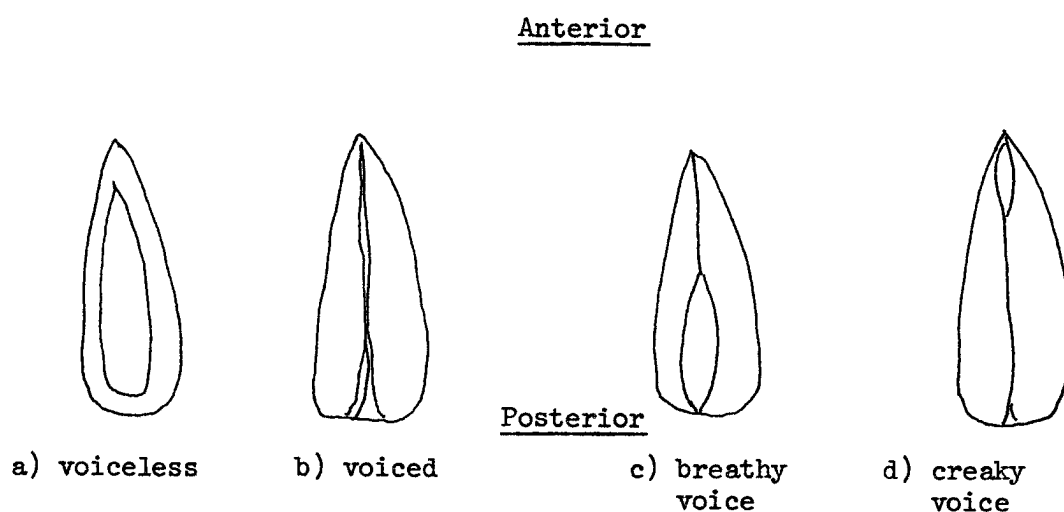


Figure 1.2: States of the Glottis During Four Different Phonation Types

In voiceless sounds, shown in (a) above, the vocal cords are apart, and cannot be set into vibration. At release of the stop closure in voiceless obstruents there is very little resistance to the air flow through the glottis, so at the onset of a vowel following a voiceless obstruent there is a very high rate of air flow, causing a rise in pitch during the initial portion of the vowel. During voiced sounds, shown in diagram (b) above, the vocal cords are close together and vibrating. During the articulation of a voiced obstruent there is a drop in air flow caused by the build up in air pressure in the oral cavity due to the stop closure. Because of this drop in air flow the vocal cords vibrate at a lower rate and the pitch is progressively lowered. At the release of a voiced obstruent the pitch of the following vowel may be initially lower, until the rate of air flow has increased to its normal level. During breathy voiced sounds, diagram

(c), the posterior regions of the vocal cords are apart, as in the voiceless sounds, but the anterior portions are close enough to be set into vibration. During creaky voiced sounds the posterior section of the vocal cords is tightly constricted and unable to vibrate while the anterior portion is involved in phonation.

These four main types of constriction serve mainly as points along what really is a continuum of constriction of the vocal cords. The degree and type of closure influence the pitch realization of at least the onset, or initial portion, of the following vowel, by increasing or decreasing the rate of air flow across the glottis.

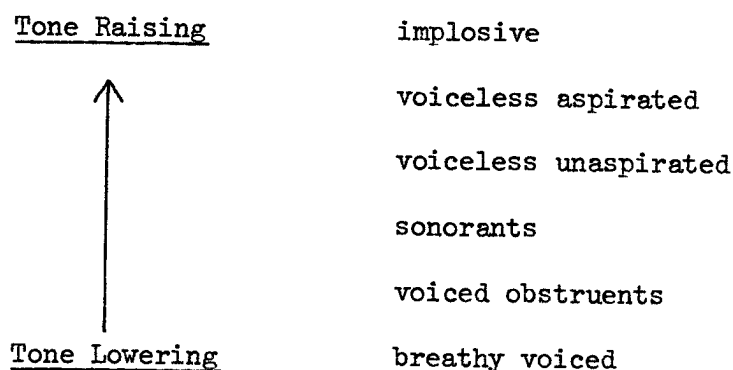
In addition to the stretching of the vocal cords, which results in variations in pitch, and the constriction of the vocal cords to form various phonation types, the larynx can be raised or lowered to change the airstream mechanisms in the articulation of sounds such as ejectives and implosives. Ejectives are articulated by closing the glottis and moving it upward compressing the air in the vocal tract. Since the larynx is raised during articulation of the ejectives, these segments might be expected to raise pitch (since a raised larynx is associated with high pitch). In implosive sounds the closed glottis is moved downward resulting in a lowered air pressure in the air cavities above the glottis. Ladefoged reports that the glottis is not completely closed during this downward movement, but a small amount of air is allowed through the vibrating vocal cords as the glottis moves downward (1964, p. 6). The rapid downward movement of the glottis causes a rapid increase in air flow across the glottis. This increased air flow would be expected to raise pitch. Indeed, Hyman and Schuh (1974) claim that implosives raise pitch more than any other segment type (see p. 110). However, it should also be noted that the larynx is at a lowered position at release into the following vowel, and, as we have seen above, a lowered larynx is quite often associated with lowered pitch.

These activities of the larynx interact in many ways. Adjustments for pitch may influence the realization of segments. For example, high tone voiced obstruents may tend to be devoiced, since the lengthening of the vocal cords to maintain the high pitch makes it more difficult to bring the vocal cords together for their entire length, to maintain voicing. Conversely, the adjustments required for certain phonation types may influence the realization of pitch. For example, creaky voice sounds are articulated with the posterior region held tightly together and the arytenoid cartilages moved forward, slackening the tension on the cords, lowering pitch. It is possible to compensate for the effect of a counteracting gesture: this must be the case since all phonation types can and do occur on all pitches and tones.

In Section 1.3, I will discuss the Hausa segmental inventory using the information given in this section as background. In Section 1.4, experimental evidence will be presented to investigate whether these Hausa segments have the effects on pitch which would be predicted by this discussion.

1.2 Universals of Segment Types and Tone

In their article, "Universals of Tone Rules", Hyman and Schuh show that in many different language families, classes of consonants have a consistent predictable effect on the realization of pitch within the syllable. They cite many interesting examples of tone rules which have the specification of segment types as conditioning factors in the governing context. They find that they can predict which classes of consonant types are more likely to have a tone raising effect, and which consonants will have a tone lowering effect on the pitch of the following vowels. They propose the following hierarchy:



They acknowledge that this tentative hierarchy is unsatisfactory because it is incomplete (ejectives, glottal stop, and creaky voice are missing), because it does not differentiate among the sonorants (they claim that "nasals may be closer to being of a tone lowering nature than, say, liquids, glides or vowels"), and because it does not mention the differences between places of articulation, and between fricatives and stops (1974, p. 110).

Gandour (1974) found that in Thai voiceless unaspirated stops raised pitch more than voiceless aspirated stops (1974, p.102). This finding is a counterexample to the universal hierarchy given above.

In Section 1.4 experimental evidence will be introduced to show to what extent the segments of Hausa conform to the findings of these researchers.

1.3 The Segments of Hausa : A Review of the Literature

In this section, an investigation into the phonetic properties of the consonantal segments of Hausa is presented. Claims in the literature about the nature of Hausa segments are presented and criticized. Following this, new experimental evidence is introduced which shows that some of the consonants have different phonetic properties than what has been traditionally claimed. For the sake of exposition, a chart of the consonantal inventory from Hoffmann and Schachter (1969) is presented in Table 1.1. Then, the claims which appear in the

	Bilabial	Labio-Dental	Alveolar	Retroflex	Palato-Alveolar	Palatal	Palatalised Velar	Velar	Labialised Velar	Glottal	Palatalised Glottal
Plosive	b		d t				g k	g k	gw kw	ʔ	ʔj
Glottalised Plosive	ɸ		ɸ				ɸj	ɸk	ɸkw		
Fricative		f	z		ʃ					h	
Glottalised Fricative			sʔ								
Affricate					dʒ tʃ						
Nasal	m		n					[ŋ]			
Flap/Tap			ɾ	ɽ							
Lateral			l								
Approximant						j			w		

Table 1.1: Hausa Consonant Chart

(from Twelve Nigerian Languages, ed. E. Dunstan, chapter six, on Hausa, written by Carl Hoffmann and Paul Schachter.)

literature about the more controversial segments are investigated.

For the sake of consistency throughout the dissertation, the phonetic symbols in this chart will be replaced by their representatives in the standard Hausa orthography:

gʝ	→	gy	ʃ	→	sh
kʝ	→	ky	sʔ	→	ts
kʝ	→	ky	ŋ	→	n
ʔʝ	→	'y	dʒ	→	j
j	→	y	tʃ	→	c
			{ ɽ ɾ	→	r

All the other segments are the same in the orthography as they are in the chart. Departing from what is found in Hausa orthography, long vowels will be written as double vowels. In addition, following the conventions of Hausa orthography, high tones will be unmarked, and low tones will be marked with a grave accent on the first vowel symbol of the syllable: kujèeraa has a HLH tone pattern. Falling tone, which is analyzed here as a high tone followed by a low tone on the same syllable, will be unmarked on the first vowel symbol and have a grave accent on the second vowel of the falling syllable: fitoòwa is high-falling-high tone.

1.3.1 Plosives

(a) While most Hausa scholars agree that there are voiced and voiceless variants of the alveolar and velar stops, there is some controversy about whether there is also a two-way contrast in the bilabial stops, or whether there is just a voiced stop. Most Hausa scholars claim that Hausa has a voiceless bilabial stop, p, only as an allophone of the voiceless bilabial fricative f. Abraham claims that the stop closure is "an occasional alternative to f" (1959, p. 2). Taylor claims that the voiceless bilabial fricative alternates with a voiceless bilabial implosive, and that "with some individuals the forceful separation of the lips (at release) is so exaggerated that it is almost like that peculiar hollow sound when a bottle is uncorked" (1959, p. xvii). Kraft and Kraft (1973), the FSI text by Hodge and Umaru (1963), and Hoffmann and Schachter (1969) also claim that p sometimes alternates with f. Hoffmann and Schachter note that f is bilabial, and that p alternates or is used in place of f word initially before /i/, /i:/, /a/, and /a:/, and in syllable-final position. Greenberg (1970), however, claims that within the standard dialect of Hausa, spoken in Kano, there are f-speakers and p-speakers. The f-speakers have a bilabial fricative which alternates with h, with h appearing before rounded vowels. The p-speakers "have a bilabial stop" and this p occurs before both back vowels. With both types of speakers h is a

separate phoneme that can occur in contrast with p or f (p. 322).

(b) According to the FSI text by Hodge and Umaru, p, t, and k are not as strongly aspirated in Hausa as they are in English.

(c) The status of the palatalized and labialized velars is a subject of controversy. Taylor claims that if a ko or go syllable is closed the velar consonant is rounded, resulting in kwa or gwa (1959, p. xvii). He also says that k is palatalized before e. Kraft and Kraft claim that both the bilabial and the velar stops may be labialized before back vowels, and that k and g may be palatalized before i and e. The FSI text by Hodge and Umaru claims that b, ɸ, k, ɸ, and g are labialized before u, o, and oo, and that the stops are released with an off-glide. All of the preceding descriptions suggest that labialization and palatalization are predictable in Hausa. Ladefoged (1964) lists the labialized and palatalized and 'plain' ejectives as separate phonemes, as do Hoffmann and Schachter. I agree that these are phonemes, since there are minimal pairs with a three-way contrast between the labialized, palatalized, and 'plain' stops:

- | | |
|-----------|--------------------------------|
| 1. kàaraa | 'being screened off' |
| kwàaraa | 'exchanging money for cowries' |
| kaarà | 'screening off' |
| kyaarà | 'pour out' |
| ƙàaraa | 'finished' |
| ƙwàaraa | 'overloaded' |
| ƙaarà | 'increased' |
| ƙyaarà | 'a kind of grass' |
| gàdaa | 'boasting' |
| gwàdaa | 'measure, test' |
| gaaraa | 'wedding gifts' |
| gyaaraa | 'repairing' |

(d) Although in the Hausa orthography words are shown to begin with vowels, all seemingly word-initial vowels are actually preceded by glottal stop. Similarly, word-final short vowels are checked by glottal stop as are some long vowels (FSI, p. 26).

1.3.2 Glottalized Plosive

These segments are the source of the greatest amount of controversy about Hausa segments.

(a) The bilabial plosive, usually written as ɓ, has been described by Taylor as a voiceless implosive alternating with p and f. Abraham says that ɓ and ɗ are implosives and are accompanied by a glottal stop. The FSI text by Hodge and Umaru says that b and d begin with a stop closure and are released with a glottal stop, but does not claim that they are implosives. Kraft and Kraft claim that these segments are articulated with simultaneous labial and glottal closure released simultaneously, and have an implosive air stream mechanism. Ladefoged says that these segments may involve a downward movement of the glottis but that the really "essential component is a different kind of voicing" (1964, p. 6). These segments are laryngealized, that is they are articulated with creaky voice. Because of this, the amplitude of these sounds is reduced during phonation since less of the vocal cords are vibrating. Ladefoged describes these sounds as being "incidentally implosive on some occasions" but stresses that they are distinguished from the other Hausa plosives by being laryngealized (1964, p. 16). Ladefoged goes on to point out that it is impossible to "separate out two kinds of glottalised consonants: what we are here calling voiced implosives (as in Igbo and Kalabari), in which there is always a downward movement of the glottis -- and there may or may not be laryngealised voicing; and what we are here calling laryngealised consonants (as in Hausa), in which there is always a particular mode of vibration of the vocal cords -- and there may or may not be lowering of the larynx" (p. 16). He says that it is very difficult to distinguish between creaky voice and glottal closure, but, whereas Chadic languages have laryngealization, in the other West African languages there is glottal closure.

(b) The glottalized velar, usually written as ƙ in the orthography, and the labialized and palatalized glottalized velar stops, usually written as kw and ky in the orthography, also have been variously described in the literature. Abraham says that this segment "is the ordinary 'k' sound modified by being forcibly ejected" (1959, p. 2). Taylor claims that this segment is the voiced counterpart of Arabic q, and that "it should be practiced by sounding the ki of our king, and then producing it a little farther back and with glottal closure (but without turning it into a g), contrast this with the voiced sound made in imitating the 'caw' of a crow well down in the throat" (1959, p. xviii). The FSI text by Hodge and Umaru says that these segments are articulated with the velar closure and "are released with a glottal stop" (1963, p. 26). Kraft and Kraft note that these segments do not have an implosive airstream mechanism. As we saw in Table 1.1, Hoffmann and Schachter do not differentiate between ɓ and ɗ on the one hand and ƙ on the other, calling them all 'glottalised plosives'. Ladefoged, in his extensive study of West African languages, found that, out of sixty-one languages, only Hausa had ejectives. He describes the ejective segments as having rapid upward movement of the closed glottis which compresses the air behind the oral closure (1964, p. 5). Ladefoged, describing the entire series of ejectives in Hausa, ƙ, kw, and ky plus the ejective s, ts in the orthography, discussed below, found that the "stops in this series were accompanied by an interval of

50-60 msec between the release of the closure and the start of the vowel. This is slightly longer than the period of aspiration following the corresponding stops c, k, and kw, which usually lasted about 35-45 msec" (1964, p. 5). (Ladefoged uses the symbol c for what is represented in the orthography as ky). This additional time before voicing onset might be required for the lowering of the glottis for normal voicing, he goes on to say.

1.3.3 Fricatives

The question of whether f was a fricative or a stop was discussed in Section 1.3.1 on plosives.

Kraft and Kraft point out that h may be articulated as a fricative, with the friction occurring in the pharyngeal cavity or in the mouth. When the lips are rounded and the friction occurs in the mouth, f may occur as an allophone of h. In other words, f occurs before rounded vowels.

1.3.4 Glottalized Fricative

Taylor describes this segment, usually written as ts in the orthography, as "the affricative sound represented in English by the 'ts' after an 's' as in 'posts'" (p. xix). FSI by Hodge and Umaru says that this segment is articulated by making a 'normal' s "released with a glottal stop" (p. 26). Kraft and Kraft call this segment a glottalized alveolar fricative -- an s with simultaneous glottal closure. He goes on to say that "alternatively it is a combination of /t/ plus /s/ with simultaneous glottal closure" (p. 25). Ladefoged describes this segment, which he claims is an ejective, in considerable detail. He says that the point of articulation of the fricative changes during its articulation; "the upward movement of the glottis is achieved by an upward movement of the hyoid bone accompanied by the contraction of the thyrohyoid muscle which links the hyoid bone and the thyroid cartilage. The hyoid bone is a small horseshoe-shaped bone below the base of the mandible; it forms the foundation for many of the muscles of the tongue. If it is moved upwards the position of the body of the tongue will be altered so that the articulatory constriction is moved forwards" (p. 5). There is an interval of 40 msec between the end of the fricative sound and the release of the glottal stop, and another short interval before regular vibration of the vocal cords begins.

The palatalized glottal, ?j, usually written as 'y in the orthography, is described by Taylor as "a voiceless y produced with glottal closure" (p. xix). FSI and Abraham do not mention the segment. Kraft and Kraft describe it as a "palatal semi-vowel with simultaneous glottal closure" (p. 26). Ladefoged says that this sound is a laryngealized consonant, distinguished from the other voiced segments by the fact that it is articulated with creaky voice. He describes a particular

example of the segment as beginning with voicelessness with the vocal cords "apparently tightly closed" followed by four irregular pulses of vibration, followed by a gap which he feels he cannot positively claim is a glottal stop, with regular vibration following. (p. 17) He includes a plate (plate 1b) showing the segment in intervocalic position.

1.3.5 Nasals

Hoffman and Schachter (1969) claim that η occurs as a syllable-final allophone of /n/.

1.3.6 Flap/Tap

Both Taylor and Abraham refer to a 'rolled r' in Hausa. Taylor distinguishes this from "a plain fricative r" (p. xviii). FSI by Hodge and Umaru distinguishes between a flap and a trilled r. Kraft and Kraft claim that one r is a fronted retroflex flap, which is "a single rapid flap of the tip of the tongue against the alveolar ridge" and the other r is described as a trill at the same point of articulation. Ladefoged says that Hausa has an alveolar tap, r, which he claims is occasionally replaced by a trill. In addition, Hausa has a retroflexed flap, r. Ladefoged points out that James and Bargery (1925), Greenberg (1941) and Hodge (1947) say that the difference between these segments is that the alveolar one is a trill and the other is a flap. Ladefoged claims that the alveolar tap is a "trill with the statistical probability of consisting of only one tap" (p. 30). He points out that these segments are extremely similar accoustically, but are very different articulatorily, in that tap "involves a rapid movement of the tip of the tongue up to tap (and occasionally to trill) against the forward part of the alveolar ridge". The flap, on the other hand, "is made by drawing the tongue tip up and back, and allowing it to flap against the posterior part of the alveolar ridge as it comes down" (p. 30).

In addition to the segments listed in Table 1.1, geminates of all the segment types occur, frequently as the result of reduplication processes.

1.3.7 An Experimental Investigation of the Consonantal Inventory

In the above review of the literature there are many contradictory and confusing descriptions of the Hausa consonant inventory. Because of this, I felt that it was impossible to discuss the hierarchy of segmental influence on pitch which Hyman and Schuh proposed, without an experimental investigation in to the exact nature of these segments.

The following segments were chosen for the experiment:

voiced stops:	b	d	g	
voiceless stops:		t	k	ʔ
laryngealized stops:	ḃ	ḏ		
laryngealized glide:				'y
ejectives:		ts	k̚	
fricatives:	f	s		
glide:				y
nasal:	m			
affricate:		c		

A corpus of Hausa words was selected so that all the words had the following characteristics:¹

- the words began with the segment to be tested
- the vowel following the initial consonant was long aa
- the segment following the initial Caa in the word was r
- the syllable containing the segment was high tone
- the syllable containing the segment was followed by at least two high tone syllables either within the word or within the frame.

Thus all the words begin with Caar. An additional requirement was that the informant be familiar with each word in the corpus. The corpus of words used in the experiments in this chapter is given below:

2.	baaruu 'hyena'	daaroorii 'basins'	gaaraa 'wedding presents'	
		taaruu 'fish nets'	kaaruuwanci 'harlotry'	areewaawaa 'Northerners'
	baaraaraa 'loud talk- ing'	daarii 'cold wind'		'yaruuwaa 'sister'
		tsaaraa 'equal'	kaarii 'bad smell'	
	faaroorii 'locusts'	saaraa 'chopping'		yarabaawaa 'Yorubas'
	maaraa 'dipper'			
		caaraa 'cock crowing'		

These words were placed in the following frames:

- 3a. Naa ga _____ cikin littaa\fin\sa.
'I saw _____ in his book.'
- 3b. Naa ga _____ baayaan k\asu\waa.
'I saw _____ behind the market.'
- 3c. _____, na ga cikin littaa\fin\sa.
'_____, is what I saw in his book'.

Since the frame given in (3a) requires a citation form, the frame in (3b) was also used to insure that there were no changes in articulation or pitch that were due to the frame. No such changes were found. The words to be tested occur sentence-initially so that the segment occurred utterance initially in sentence (3c), and medially, so that the segment is intervocalic, in sentences (3a) and (3b); the use of these two frames showed which characteristics of the segments, if any, were due to position within the utterance or to assimilation to surrounding segments. The fact that several syllables follow the test words before the end of the sentence in these frames avoided the possibility that sentence final intonation, which lowers the last few syllables of a Hausa utterance with downdrift, would affect the pitch realization of the test syllables, or that the segments themselves would be affected by this lowering. The sentences were then arranged in a list so that consecutive utterances were not likely to be read with contrastive stress; i.e. they were arranged so that the words with the least phonetic and semantic similarities were in sequence. The informant read the corpus in the sound-proof booth in the UCLA Phonetics Lab. Eleven recordings were made of the corpus with the words in medial position, and four recordings were made of the words in initial position. These recordings were analyzed in this experiment. If some non-linguistic factor, such as machine failure, made a given token invalid it was discarded. In addition, the informant read the entire corpus four times wearing the electroglottograph to record the movements of his vocal cords. This provided me with both acoustic and articulatory evidence. An oscillogram recording was made of these tapes with input from a pitch meter, an electroglottograph, and an amplifier. In order to determine the nature of the Hausa consonants, the wave form, electroglottograph channel, and the intensity were analyzed. The pitch channel was used for the experiment in the next section. A computer program was also used which provided a pitch and intensity measurement for every ten milliseconds of the utterance. These measurements of pitch and intensity were useful in determining such characteristics as voicing and aspiration, in addition to the oscillogram recordings. Those results of the investigation which differed from what had been reported in the literature are discussed below.

1.3.8 Plosives

(a) It is very difficult to determine conclusively from the recordings whether there is a bilabial voiceless stop in my informant's speech, either as an allophone of the bilabial fricative, or as a non-alternating segment. Very little friction is apparent in the wave form of this segment, nor does much friction appear as high frequency noise in the pitch recording. However, the segment is not sharply released, as would be expected of a voiceless stop in Hausa, these latter segments also being accompanied by aspiration upon release. Figure 1.3 is the oscillogram recordings of the wave forms of portions of the following utterances:

- (4) Naa ga faaroorii cikin littaafinsa.
'I saw locusts in his book.'
- (5) Naa ga taaru cikin littaafinsa.
'I saw fish nets in his book.'
- (6) Naa ga kaaruwanci cikin littaafinsa.
'I saw harlotry in his book.'
- (7) Naa ga saara cikin littaafinsa.
'I saw chopping in his book'

Note that in Figure 1.3 the bilabial segment, f, is similar to the voiceless stops, t and k, lines 2 and 3, in that it appears to be voiceless, with very little noise. It differs from these voiceless stops in that it is not released with aspiration. It also differs from the voiceless fricative s, line 4, in that it has much less noise, but is similar to this segment at the point of release. It seems, therefore, that the segment is most probably a bilabial voiceless fricative, and not a stop, at least for my informant. (Since all of my recordings were of the bilabial segment followed by long aa, I was not able to determine whether my informant had h as an allophone of f before back rounded vowels as Greenberg claimed).

The evidence also showed that the voiced stops, b, d, and g were often not fully voiced, but had periods of voicelessness during their articulation. In initial position in the utterance, b was fully voiced in one token out of the four recordings; in the other recordings the segment began with voicing which decreased to voicelessness for about 20 msec, and was followed by voicing again before onset of the vowel. Intervocally, the segment was fully voiced only 3 out of 11 times, again showing a pattern of voicing, followed by about 20 msec of voicelessness, followed by voicing. The alveolar voiced stop, d, had the same pattern as the b in initial position. Intervocally, none of the 11 tokens was fully voiced. The alveolar stops were less voiced than the bilabial stops. In initial position only one token out of four was fully voiced, the other three tokens having the equivalent of two to three periods of voicelessness in the middle of the segment, and in intervocalic position the initial

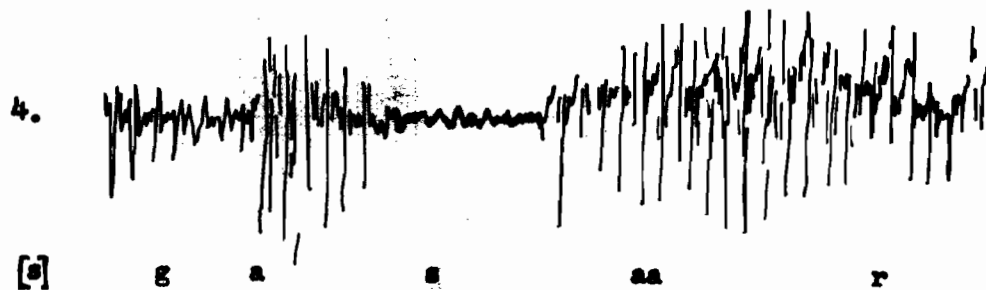
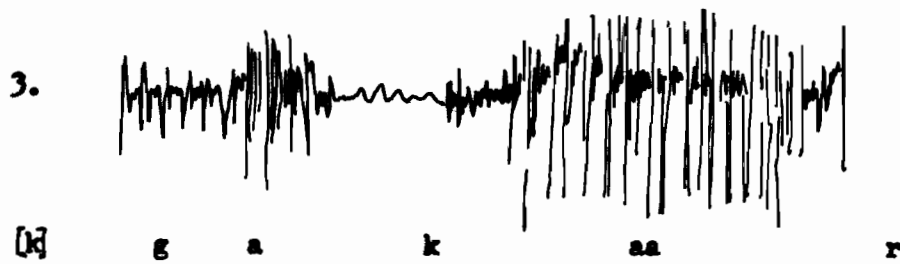
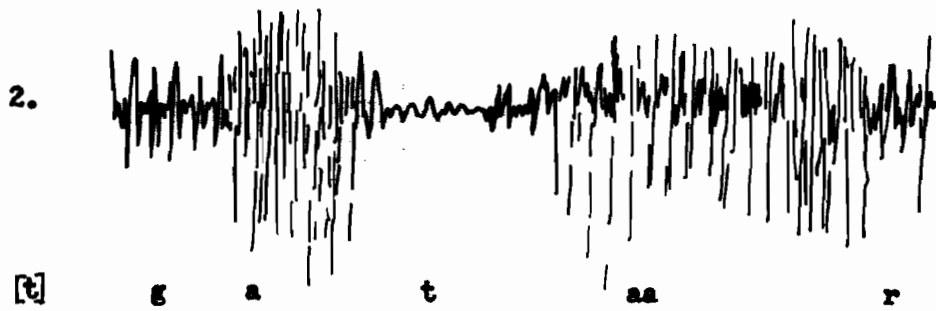
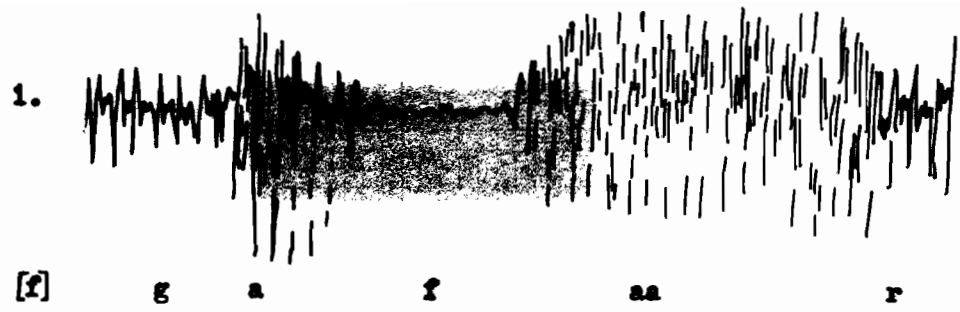


Figure 1.3: Wave forms of f, and the voiceless stops t and k, and the voiceless fricative s.

portion of 7 of the tokens was voiceless, with voicing towards the end of the segment before release into the vowel. The velar voiced stop, *g*, was never fully voiced, even in initial position. The velar segments were more voiceless than the alveolar stops. It was also surprising to find that all the voiced stops were more fully voiced in initial position than intervocalically, since voicing is natural and unmarked in an intervocalic environment.

The electroglottograph recordings of these segments also showed that these segments were, at times, articulatorily voiceless, that is, the vocal cords ceased to come together during some portion of their articulation. Again, the velars showed the greatest amount of voicelessness, the alveolars were more voiced than the velars but less voiced than the bilabials; the bilabials were almost fully voiced. The decrease in voicing as the place of articulation gets nearer to the glottis is presumably due to the decrease in size of the vocal cavity, with a consequent decrease in the possible transglottal air flow.

1.3.9 Glottalized Plosives

My data show that the bilabial and alveolar glottalized plosives are, in fact, voiceless. In Figures 1.4 and 1.5 the wave forms and electroglottograph recordings of the bilabial and bilabial glottalized stops, and of the alveolar and alveolar glottalized stops are presented for comparison. Figure 1.4, lines 1a and 1b are of portions of utterance (8), lines 2a and 2b are of portions of utterance (9):

- (8) Naa ga baaru cikin littaaɸɪnsà
'I saw hyena in his book.'
- (9) Naa ga baaraaraa cikin littaaɸɪnsà
'I saw loud talking in his book.'

In line 1a, Figure 1.4, the wave form of the bilabial stop b, shows that it is voiced. Line 1b, the electroglottograph recording of the same token, also shows that the vocal cords are close together and vibrating during the articulation of the segment. Line 2a, the wave form of the glottalized stop ɸ, show that this segment has no audible voicing and is unaspirated; line 2b, the electroglottograph recording of the same token, shows that during the initial portion of the oral closure there are two or three oscillations that may be vibrations of the vocal cords occurring at irregular intervals as in laryngealized voice. It is also the case that the release of the ɸ into the following vowel very closely resembles the same period of transition in the voiced stop. Of the eleven recordings made of this segment in intervocalic position, none had voicing for a considerable time before release of the articulation of the segment, and none of the four recordings of this segment in initial position showed voicing during the segment.

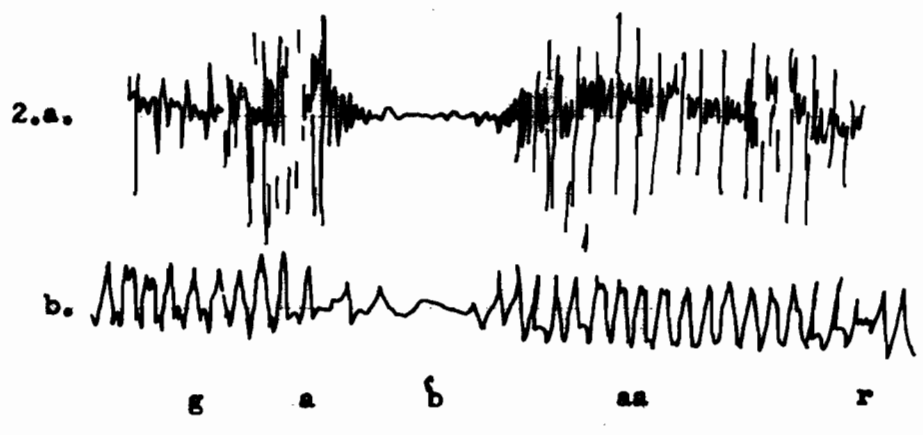
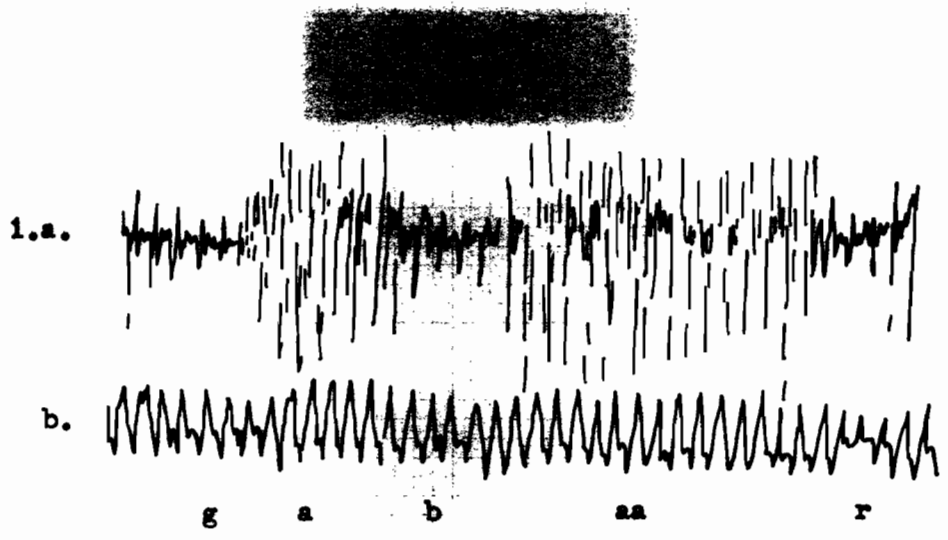


Figure 1.a: Waveforms and electroglottograph recordings of g and b.

Since Hausa does not have a three-way contrast of voiced, voiceless and glottalized bilabial stops, the alveolar series is shown in Figure 1.5, this time with the glottalized segment in utterance initial position. Lines 1a and 1b are of portions of utterance (10), lines 2a and 2b are of portions of utterance (11), and lines 3a and 3b are of portions of utterance (12):

- (10) Daaroorii na ga cikin littaaɸɪnsà
'Basins is what I saw in his book.'
- (11) Ɗ̥ aarii na ga cikin littaaɸɪnsà
'Cold wind is what I saw in his book.'
- (12) Taaruu na ga cikin littaaɸɪnsà
'Fish nets is what I saw in his book.'

Again, lines 1a and 1b show that the d is voiced although it is less fully voiced than the b in Figure 1.4. Lines 2a and 2b show that the glottalized segment has no audible voicing and is unaspirated, while lines 3a and 3b show that the segment t̥ is voiceless and aspirated. The period of transition into the following vowel is very similar in the 'plain' voiced and the glottalized segments. Of the eleven recordings made of d̥ in intervocalic position, none had voicing during the segment and none of the utterance initial recordings of this segment had any voicing.

Ladefoged claims that in the glottalized bilabial and alveolar segments in Hausa "the creaky voice is most evident not during the stop closure itself but during the first part of the following vowel" (1975, p. 124). At least for my informant, there was a period of irregular voicing lasting about 40 msec at the transition into the vowel with these segments. However, the wave form and electroglottograph channel of the voiced stops showed the same kind of transitional patterns. (There are differences in the pitch patterns of these segments. These will be discussed in Section 1.4).

In both Figures 1.4 and 1.5, lines 2b, the electroglottograph recordings of the glottalized segments, there is perturbation during the initial portion of the segments. This could be due to movement of the glottis. It is probable that there is glottal closure as well as bilabial or alveolar closure during the articulation of these segments, with simultaneous release of both closures.

1.3.10 Ejectives

The velar ejective, k̥, has a very different mode of articulation from the other glottalized stops, according to Ladefoged (see Section 1.3.2). In Figure 1.6, the glottalized and non-glottalized velar stops are presented for comparison. Lines 1a and 2b are of portions of utterance (13) and lines 2a and 2b are portions of utterance (14):

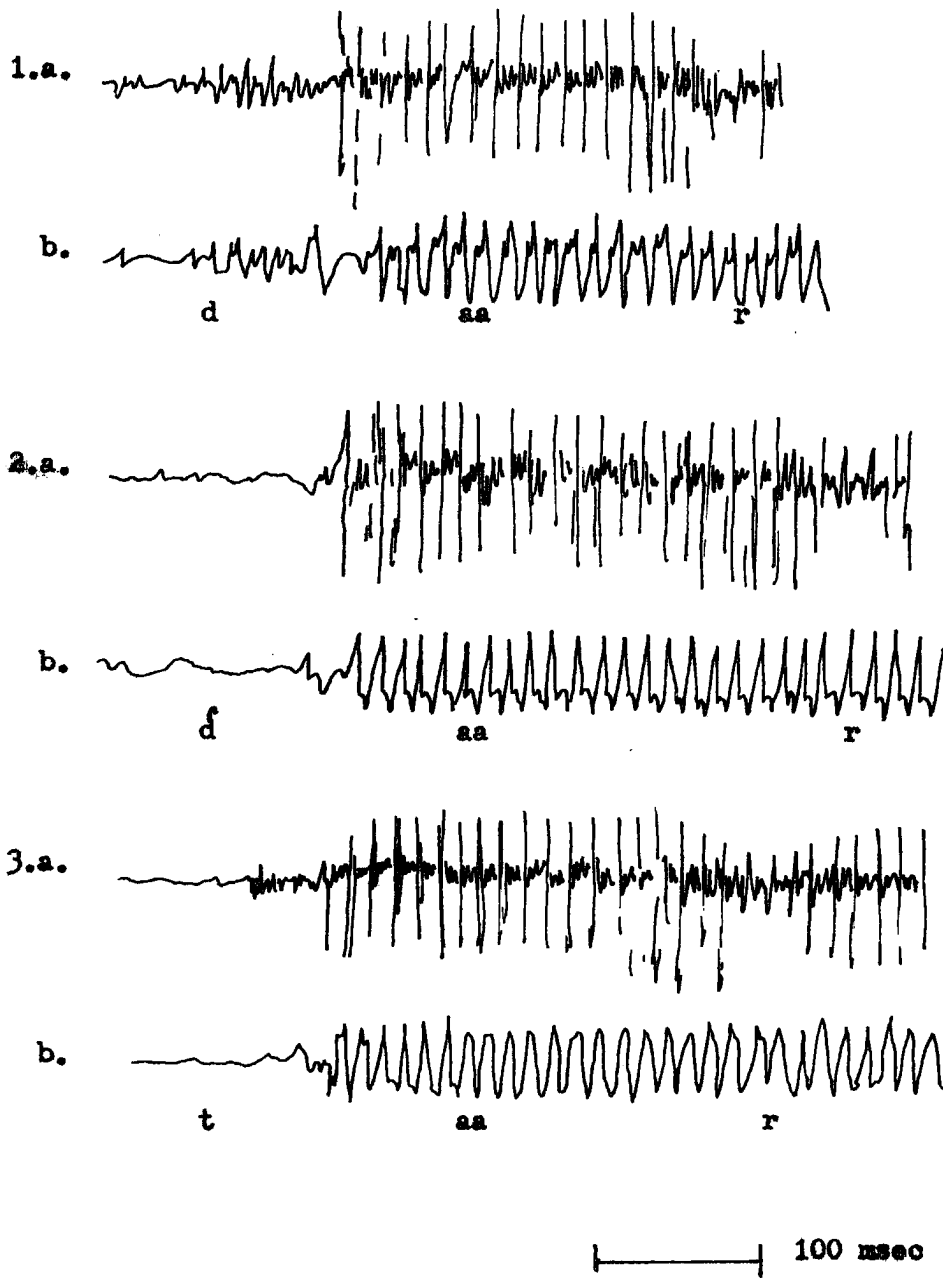


Figure 1.5: Wave forms and electroglottograph recordings of d, d', and t.

- (13) Naa ga kaaruwanci cikin littafinsà
'I saw harlotry in his book.'
- (14) Naa ga kaarii cikin littafinsà
'I saw bad smell in his book.'

In Figure 1.6, lines 1a and 1b, the wave form and the electroglottograph recording of the non-glottalized velar, k, we can see that the segment is voiceless throughout, and that it is aspirated immediately before the onset of voicing in the vowel. In lines 2a and 2b, the wave form and the electroglottograph recording of the glottalized velar, k̚, we can see that there is no voicing in the segment, presumably because the vocal cords are held together in a glottal stop. After the release of the velar closure there is a burst of noise (probably accompanied by aspiration), after which there is a delay of about 40 msec before the onset of voicing in the vowel. There is some irregular laryngeal activity during this period, as seen on the electroglottograph channel, line 2b. This could be either movement of the larynx, or irregular laryngealized voicing. Comparing the voiceless velars and the velar ejectives in utterance-initial and medial positions I found the following differences. First, the glottalized segment, k̚, is, on the average, longer. The glottalized segment lasted an average of 150 msec, while the non-glottalized segment lasted an average of 120 msec. Second, the glottalized segment had an average of 40 msec delay with some irregular laryngeal activity before onset of the vowel, while the non-glottalized segment had aspiration immediately before onset of the vowel. All four recordings of the ejective in utterance-initial position and eight out of the eleven tokens of the ejective in medial position had the pattern just described. Three out of the eleven recordings in medial position seem to have no voicing during the stop closure, followed by release of the velar closure and a burst of noise, followed by another period of silence without voicing, presumably while the glottal closure is maintained, before onset of the vowel. It would be expected that the ejectives, because of the longer delay between release of the velar stop closure and the onset of voicing in the vowel, will have a very different effect on pitch of the following vowel than either the glottalized bilabial and alveolar segments, or the voiceless velar stop.

Ladefoged claimed that the glottalized fricative or, more properly, the ejective s̚, consisted of a period of friction followed by another 40 msec during which the glottal stop that occurred during the friction was maintained, followed by another short interval before the vibration of the vocal cords for articulation of the vowel begins. In Figure 1.7 the non-glottalized fricative s, and the glottalized fricative s̚ are shown for comparison. Lines 1a and 1b are of portions of utterance (15) and lines 2a and 2b are portions of utterance (16):

- (15) Saaraa na ga cikin littafinsà
'Chopping is what I saw in his book.'

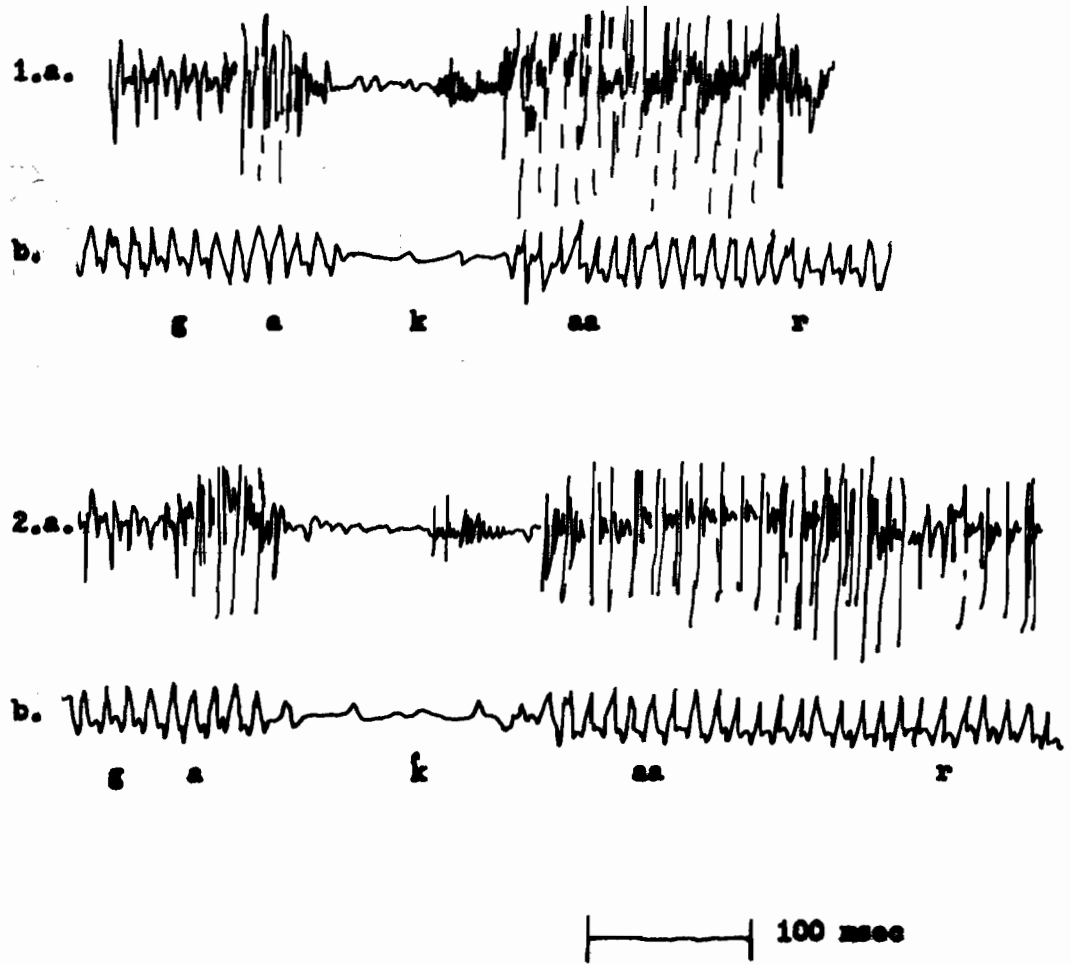


Figure 1.6: Wave forms and electroglottograph recordings of \underline{k} and $\underline{\bar{k}}$.

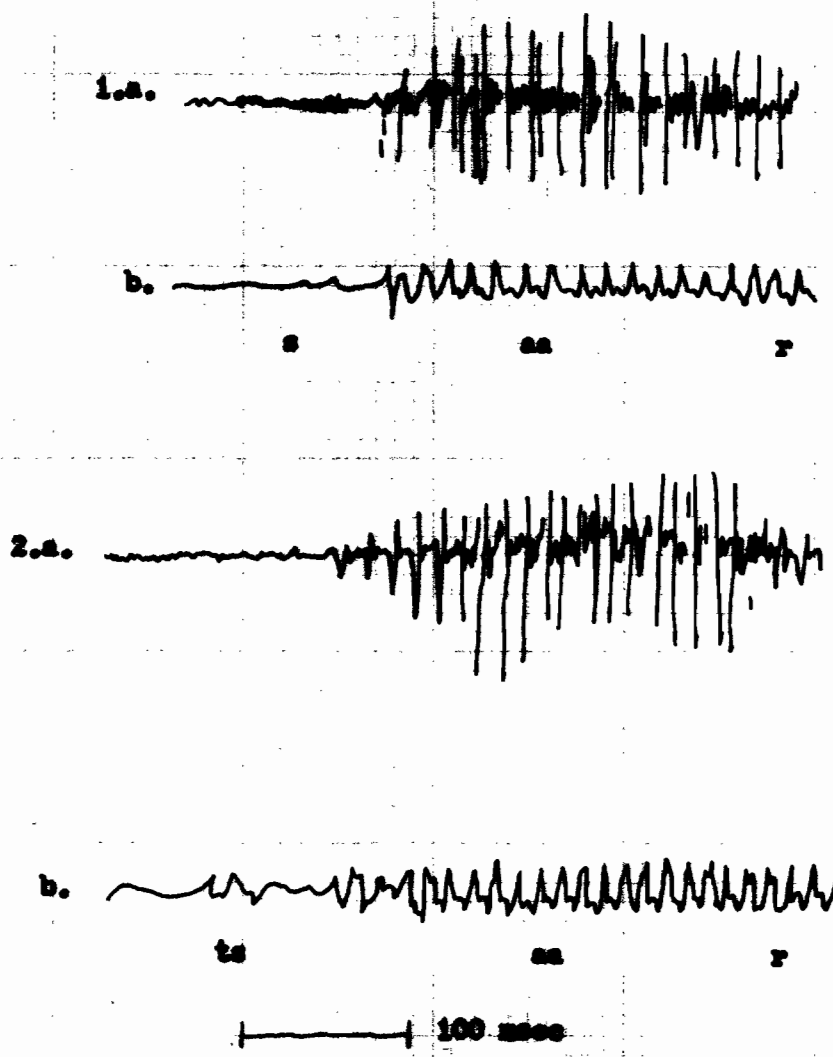


Figure 1.7: Wave forms and electroglottograph recordings of a and ts.

- (16) Tsaaraa na ga cikin littaaɸɪnsà
'Equal is what I saw in his book.'

In lines 1a and 1b, the wave form and electroglottograph recording of the non-glottalized segment, it can be seen that s is voiceless and has friction throughout. In Figure 1.7, lines 2a and 2b, the wave form and electroglottograph recording of the laryngealized fricative, we can see that the segment begins with friction, which is visible on the wave form, which is followed by some laryngeal activity, probably associated with upward movement of the closed glottis, which can better be seen on the electroglottograph channel, followed by about 50 msec of voicelessness where there is no laryngeal activity, followed, in turn, by about 50 msec of irregular voicing which is most visible as irregular vibrations of the vocal cords on the electroglottograph channel, before the more regular vibrations of the vowel begin. Comparing the 14 recordings of these two segments I found the following differences. First, the glottalized segment is longer; it averaged 120 msec in length, while the non-glottalized segment averaged 80 msec. Second, the non-glottalized segment begins with an average of 40 msec of friction followed by a short voiceless period, followed by a rather long period, 50-60 msec, of irregular voicing that is probably creaky voice. The non-glottalized segment has friction throughout. These two segments have different effects on pitch, which we will discuss in the next section. The fact that the glottalized fricative ends with creaky voice predicts a different effect on pitch than would be expected if the segment was voiceless just before release.

1.3.11 Glottalized Glide

The glottalized y usually written as 'y in the orthography, also differed from the descriptions found in the literature. In Figure 1.8, the wave forms of the non-glottalized y, the glottalized y, and the glottal stop are presented for comparison. Line 1 is of a portion of utterance (17), line 2 is of a portion of utterance (18) and line 3 is of a portion of utterance (19):

- (17) Naa ga yarabaawaa cikin littaaɸɪnsà
'I saw Yorubas in his book'
- (18) Naa ga 'yar 'uuwaa cikin littaaɸɪnsà
'I saw sister in his book'
- (19) Naa gaa ?areewaawaa cikin littaaɸɪnsà
'I saw Northerners in his book'

In line 1 the *glide*, y, is voiced throughout. In line 2, the *glottalized y*, the voicing within the glide decreases; in the mid-point of the 'y there seems to be a period of voicelessness that lasts about 40 msec, followed by a period of irregular voicing lasting approximately 40 msec; this could well be creaky voice. Of the 14

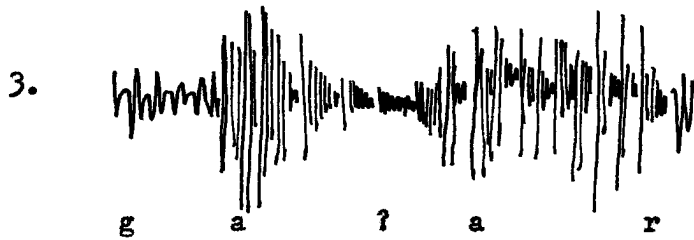
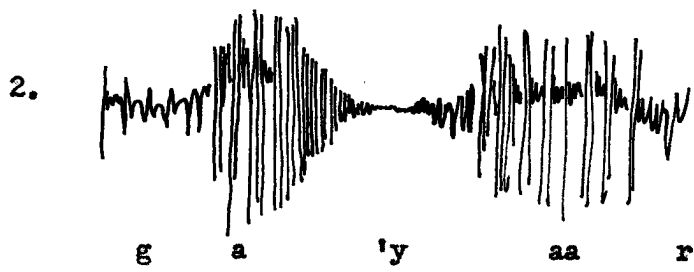
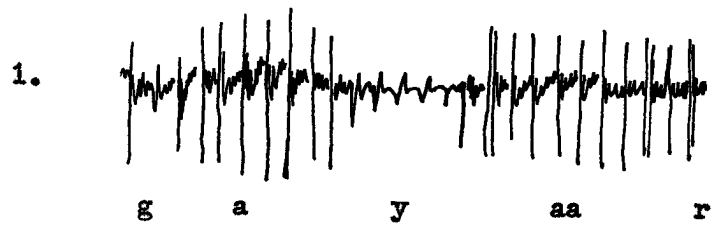


Figure 1.8: Wave forms and electroglottograph recordings of y, 'y, and ?.

recordings of the glottalized y in intervocalic position, all 14 had an initial period of voicelessness lasting an average of 35 msec. However, the recordings differed a lot, some of the segments began with 10 msec of voicelessness and others began with 70 msec of voicelessness. This was followed by an average of 60 msec of irregular voicing which continued into the vowel.

The *glottal stop* line 3, Figure 1.8, has a very unexpected wave form. It never decreases to voicelessness; there does not seem to be complete closure at any point, and there seems to be 5 pulses of voicing that decrease in intensity as the segment progresses. Just before transition into the vowel there is a period of irregular voicing that lasts about 20 msec. The 9 recordings of the glottal stop in intervocalic position are very difficult to interpret, they differ from each other more than the other segments do. These segments are voiced throughout all the recordings except for one recording with 40 msec of voicelessness. The voicing patterned in the following way: there are 2-3 pulses of voicing which decrease in amplitude and pitch as the segment progresses. The four recordings of glottal stop in initial position showed that the segment was initially voiceless with 30-50 msec of higher pitched, irregular voicing before onset of the vowel.⁴

1.3.12 Flap/Tap

It was very difficult to distinguish between the flap and the tap in my informant's speech. He never had a tap that sounded like a trill. These segments were not investigated for that reason.

1.3.13 Geminates

All of the segments described in the consonantal inventory proposed by Hoffman and Schachter (1969) can also occur as geminates. There were no articulatory differences within the segment, aside from length, between the geminates and the 'single' consonants.

1.4 The Influence of Consonants on Pitch in Hausa

In this section, I will present the results of an investigation into the effects that consonants have on pitch in Hausa. The following segments were chosen for the investigation -- their phonetic properties were described in detail in the preceding section:

(20) The Segmental Inventory

- b, d, g: Voiced stops which may be voiceless in the middle of the segment for a short period. Velars are least voiced, alveolars more voiced, and bilabials fully, or almost fully, voiced.
- ɸ, ɗ: Voiceless unaspirated stops, perhaps having simultaneous glottal closure.
- t, k: Voiceless aspirated stops.
- ʔ: Ejective stop, with a period of voicelessness. There is a burst of noise at release of the consonant, probably accompanied by aspiration, followed by approximately 80 msec irregular voicing or voicelessness before regular onset of voicing in the vowel.
- s: Voiceless fricative.
- ts: Ejective fricative : 40 msec of friction followed by a period of voicelessness, perhaps with simultaneous glottal closure, followed by 50-60 msec of irregular voicing before onset of the regular voicing in the vowel.
- c: Voiceless affricate.
- ʔ: Voiced glottal approximant; does not have complete closure or voicelessness during its articulation in intervocalic position. When it occurs utterance initially or as a geminate, the segment may be voiceless and have glottal closure.
- ʕ: Glottalized glide which begins voiced, followed by a period of voicelessness, probably accompanied by glottal closure, followed by irregular voicing which is probably laryngealized.
- ɣ: Voiced glide.
- m: Bilabial nasal.

The corpus which was given in section 1.3 was used for this experiment. The words were placed in the following frames:

- (21) Naa ga _____ cikin littaaafinsa.
'I saw _____ in his book.'
- (22) Naa ga _____ baayaan kaasuwaa.
'I saw _____ behind the market.'

The corpus was recorded four times with the words in the frame in (22), and compared with the recordings of the words in the frame in (21) to see whether the words were read with citation intonation in (21), resulting in a higher pitch on the token words in this frame. No such intonational differences were found. For this experiment the words were placed in the frame in (21) and recorded 11 times in the sound-proof booth. The pitch measurements used throughout this section were obtained through the use of a hardware pitch meter combined with a computer program which extracts fundamental frequency measurements for every 10 msec of the utterance. A tape recorder was connected to (1) a hardware pitch meter which produced a voltage proportional to the instantaneous fundamental frequency (i.e., the reciprocal of the interval between vocal cord pulses), and (2) a speech power circuit which produced a voltage proportional to the speech power. These two voltages were fed into the computer. The data were printed out on a line printer, and the print-out was analyzed using the changes in pitch and intensity to aid in segmentation. Oscillomink recordings were also used. The tokens were analyzed to see what pitch effects the segments had. Since the segments being investigated were surrounded by high tone syllables only, any perturbations could be interpreted as being the results of the intervening segments. Approximately 500-800 msec of each token were analyzed, using the vowel in ga of the frame (see (28)) as a starting point and the drop in pitch and intensity signaled by the r in each token as the end point of the measurement. Fromkin and Rodman (1974) point out that "despite the fact that the sounds we produce and the sounds we hear and comprehend are continuous signals, everyone who has ever attempted to analyze language has accepted the notion that the speech utterance can be segmented into individual pieces. According to an ancient Hindi myth, the god Indra, in response to an appeal made by the other gods, attempted for the first time to break speech up into its separate elements. After he accomplished this feat, according to the myth, the sounds could be regarded as language" (p. 31). Since I didn't have the god Indra to help me, I had to attempt, rather arbitrarily, to determine the exact point of the transition which marks the end point of the consonant and the beginning point of the vowel. The wave form and intensity channels made segmentation less difficult.

Four sections of each token were measured; a schematic representation of the sections is given in Figure 1.9.

(23) Sections of the tokens which were analyzed:

1. *The vowel preceding the consonantal segment being investigated.* This is the a in the word ga in the frame, and will be referred to as the ga-vowel. This section is shown in (1) in Figure 1.9.
2. *The onset.* The onset is considered to consist of any pitch changes which occurred immediately prior to transition into the vowel following the consonantal segment. For example, some voiced stops had a rise in pitch within the consonant just before transition into the following vowel. This rise in pitch is the onset. In Figure 1.9, this section is shown in (2).
3. *The transition.* The transition consists of those perturbations of pitch within the initial portion of the vowel which may be the result of the preceding consonantal segment. In Figure 1.9, this section is shown in (3).
4. *The vowel following the segment being investigated.* This vowel, which will be referred to as the C-vowel, is shown in Figure 1.9, in (4).

Within each section certain pitch measurements were selected for the experiment. The last three sections were always measured *relative to* the pitch of the ga-vowel. For the onsets and the transitions, the first pitch of the onset or transition recorded by the pitch meter was compared with the final pitch recorded for the ga-vowel. When comparing the ga-vowel and the C-vowel the following strategies were used to define the pitch of each vowel. If the vowel had a rising or falling contour, the beginning and end points of the vowel were used. If the vowel was steady state, a single pitch measurement was used. If the vowel alternated between two or three pitches, these pitches were used. Some vowels had complex contours, falling-rising-falling, or rising-falling-rising; with these vowels, the beginning, mid-point, and end pitches were used. When comparing the two vowels to see what effect the consonantal segment had had on the C-vowel as a whole the pitches used for each vowel were averaged, and the averaged pitches of the two vowels were compared. (With the exception of the glottal approximant, there were no vowel contours which could be predictably associated with the preceding consonantal segment. For example, although a fall within the *transition* period could be reliably associated with a voiceless stop, within the *body* of the vowel (after transition) there was no single contour which could be associated predictably with voiceless stops. All the contours described above occurred with all of the segments. The glottal approximant, on the other hand, consistently had a rising onset followed by a C-vowel with a rising contour.)

To ensure that the pitch recordings did not differ significantly from each other due to machine error, or operator error, resulting in differing results during different processing sessions, and to ensure that the segmentation strategies were being consistently adhered to, a reliability test was conducted. Comparisons were made of the pitch measurements obtained by processing the first token of each segment

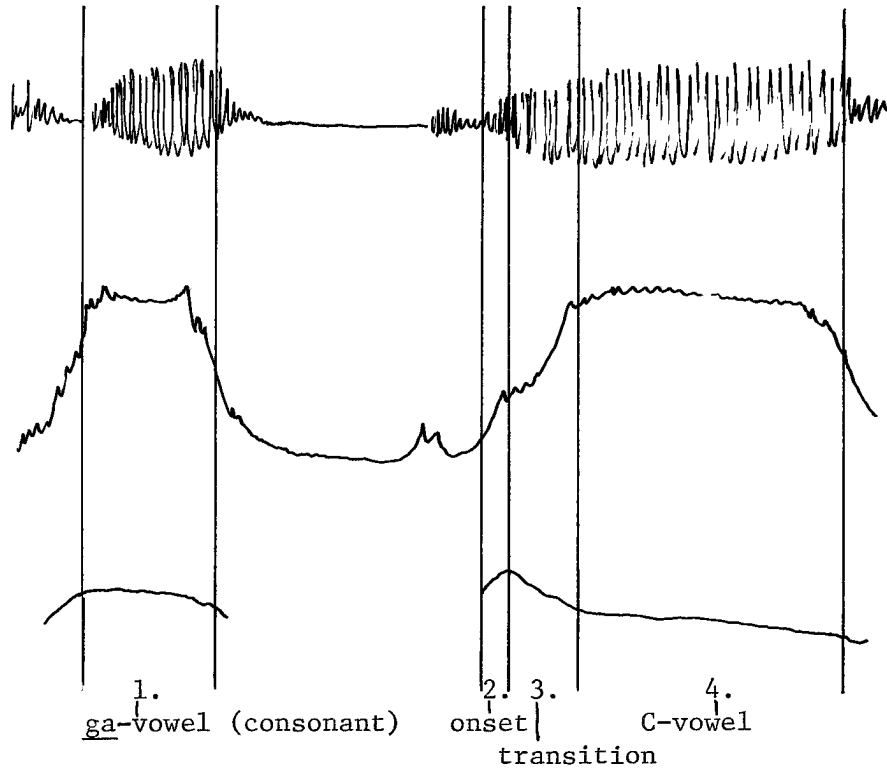


Figure 1.9: Schematic representation of the sections analyzed for each utterance.

type on two different days. Five sections were measured for each pair of recordings; these sections were, (1) the beginning point of the ga-vowel, (2) the end point of the ga-vowel, (3) the beginning point of the transition, (4) the beginning point of the C-vowel, (5) the end point of the C-vowel. (The onsets could not be used for this test since there were not enough tokens with onsets.) A Pearson's Product Movement correlation was calculated for each segment. A highly significant correlation was found between the measurements made on different days. (For (1), $r = .9749$, (2) $r = .9767$, (3) $r = .9771$, (4) $r = .9792$, (5) $r = .9903$). To determine that the segments differed from each other more than they differed from token to token within each segment type -- to determine that there was a significant main effect of the consonantal segments on the following portions of the utterance, a one-way analysis of variance was performed. There was statistically more variation between segment types than within each segment type, both at transition ($F = 10.447$, $p < .0005$) and within the body of the vowel after transition. ($F = 6.554$, $p < .0005$)

In sections 1.4.1 through 1.4.10 the findings for the *individual* segments and consonant types are presented. In section 1.5.1 the findings for *all* the individual segments are compared and discussed. In section 1.5.2 the various consonant *types* or *classes* are compared. Finally, in section 1.5.3, the significance of the findings are discussed.

1.4.1 Voiced Stops

The pitch measurements which were obtained for the voiced stops are given in Tables 1.1, and 1.2. The numbers given in these and all subsequent tables can be interpreted as follows: if the numbers are separated by dashes, i.e., 112-109-112, this represents a pitch curve which begins at 112 hz falls to 109 hz and rises again to 112 hz. If the numbers are separated by / , i.e., 100/101, the pitch alternated between these two pitches. If the numbers are listed, i.e., 100 104 100 112, the pitches occurred in the sequence given, with no intervening pitches. The *onset*, *transition*, and *C-vowel* columns are each followed by a column labeled *diff*. In the *onset* and *transition* sections, the *diff* column contains measurements of the difference between the final pitch of the ga-vowel and the initial pitch of the onset or transition. In the *C-vowel* section, the figures in the *diff* column represent the difference between the average of the ga-vowel and the average of the C-vowel.

The measurements for the voiced stops yield the following results:

Table 1.1: VOICED STOPS: b, d

	<u>qa-vowel</u>	<u>onset</u>	<u>diff</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
b							
1.	112-109-112	106	-6	none	---	112-109-112	0
3.	101/100	107	+7	109	+9	100/101	0
4.	116/114/115	117	+2	119	+4	114/116	0
5.	99/100	none	---	none	---	99/100	0
6.	104/108	91	-17	none	---	108/111	+3
7.	106-104	100 104 100 112	-4	114	+10	107-104	0
8.	99/100	96	-4	none	---	99/100	0
10.	111-114-113	none	---	115	+2	111/114	0
11.	106/104	102 105 104 109	-2	112	+8	104/106	0
d							
1.	94-97-96	none	---	100 98	+4	95/97	+1
2.	105-103	96	-7	none	---	104-100/101	-3
3.	103-102-104	none	---	none	---	104-101-104	-1
4.	101-102-100	none	---	103	+3	100/98	-2
5.	96/95	none	---	101	+6	96/97	+1
6.	98	94	-4	103 100	+5	100-96-100	0
8.	88-91	82	-9	(128) 114 97	+23	91-88-91	+1
9.	90/92	105	+13	(129) 99 93	+7	85/83	-7
10.	98-95-96	none	---	99	+3	97-95-97	0
11.	99-98	none	---	102	+4	98-96-99	0

Table 1.2: VOICED STOP: g

<u>g</u>	<u>ga-vowel</u>	<u>onset</u>	<u>diff</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
2.	98-97	none	---	101	+4	100/97	+1
3.	104-102-103	none	---	107 106	+4	104-102-104	0
4.	100	none	---	none	---	102-97-102	0
5.	96-98-96	none	---	100	+4	98-96-95-96	0
6.	98-96-95	94	-1	98 97	+3	96-94-96	-1
7.	97/95	none	---	101 98 97	+6	97/95	0
8.	91-90	88	-2	92	+2	90-86-90	-2
9.	96/97	101	+4	103 100 97	+6	96/95	-1
10.	90-92	none	---	(128) 109 99	+17	92-88-92	-1
11.	98/99/97	97	0	99 99 98 98	+2	97-95-97	-2

(24) Results for the voiced stops

	b	d	g	all voiced stops
number of <i>tokens</i>	9	10	10	29
number of <i>onsets</i>	7	4	3	14
average effect	-3.4 hz	-1.7 hz	+ .33 hz	-2.1 hz
average length	18 msec	10 msec	10 msec	12 msec
number of <i>transitions</i>	5	8	9	22
average effect	+6.6 hz	+6.8 hz	+5.3 hz	+6.1 hz
average length	10 msec	17 msec	22 msec	15 msec
comparison of <u>ga</u> -vowel with C-vowel	+ .33 hz	- .80 hz	- .60 hz	- .37 hz

With the voiced bilabial stop, b, seven out of nine of the tokens have onsets; five of the onsets begin at a lower pitch than the vowel preceding the stop. The average onset lowers pitch 3.4 hz and lasts 18 msec. The onsets might be claimed to have a pitch-lowering effect on the following vowel. However, this pitch-lowering effect is counter-balanced by the transitions, five of which are higher in pitch than the vowel preceding the voiced stop. The average transition *raises* pitch 6.6 hz. When comparing the pitches of the vowels preceding and following the stop (without transitional effects), to determine whether the voiced stop raises or lowers pitch on the syllable as a whole, it was found that the pitch of the two vowels was equal in eight out of the nine tokens, and the pitch of the C-vowel was higher (+3 hz) in one token. The voiced alveolar stop, d, has fewer pitch lowering onsets (four), than the bilabial stop, and more, longer, pitch-raising transitions (eight). The pitch of the C-vowel is .80 hz lower than the pitch of the ga-vowel. With the voiced velar stop, g, only three out of the nine tokens have pitch-lowering onsets, while eight out of the nine tokens have pitch-raising transitions. Point of articulation is directly correlated with changes in the fundamental frequency with the voiced stops. As was discussed in section 1.3.8, **the voiced** stops are usually not fully voiced, with the bilabials **being** the most fully voiced, the alveolars less fully voiced, and the velars being the least voiced. It was noted in that section that this decrease in voicing as the place of articulation gets nearer to the glottis is probably due to a decrease in the size of the oral cavity causing a decrease in the possible transglottal air flow. There seems to be a direct relationship between the size of the oral cavity and the number and effect of onsets, and the number and length of transitions:

b	d	g
largest oral cavity	smaller oral cavity	smallest oral cavity
most voicing	less voicing	least voicing
most onsets	fewer onsets	fewest onsets
onsets lower most	onsets lower less	onsets don't lower
fewest transitions	more transitions	most transitions
shortest transitions	longer transitions	longest transitions

These findings differ from those of Lea (1973) and Hombert (1975) for English. They claim that although a prevocalic consonant may affect the fundamental frequency of the following vowel, their data show that "these values do not seem to vary depending on place of articulation" (Hombert, p. 28). In section 1.4.2 similar differences, dependent on point of articulation, are found for the voiceless stops. My findings for Hausa support Hyman and Schuh's prediction that "it will be necessary to distinguish within a consonant type between places of articulation" (1974, p. 110).

The voiced stops, as a class, have the following characteristics. Only fifteen out of the twenty-nine tokens have low onsets, and the average lowering of the onsets is 2.1 hz. The onsets are short, lasting an average of 12 msec. Twenty-two of the tokens have transitions which begin at a pitch which is higher than the final pitch of the preceding vowel; the average transition begins 6.1 hz higher than the last pitch of the preceding vowel. If the onsets and transitions are considered together, the voiced stops have a short onset followed by a short transition which raises pitch. If the onsets and the transition periods are excluded, the vowel which follows the voiced stop is at almost the same pitch as the vowel which precedes the voiced stop; the C-vowel is .37 hz lower than the ga-vowel. These findings for the voiced stops in Hausa differ from the findings for voiced stops in other languages. For example, Lea found that for English "there is a general tendency for F_0 to *fall* at the beginning of voiced medial consonants, and *rise* at the beginning of the following vowel, yielding a distinctive "valley" which marks the presence of voiced consonants" (1973, pp. 33-34). Lea provides the following figure representing a typical F_0 contour for voiced consonants in English:

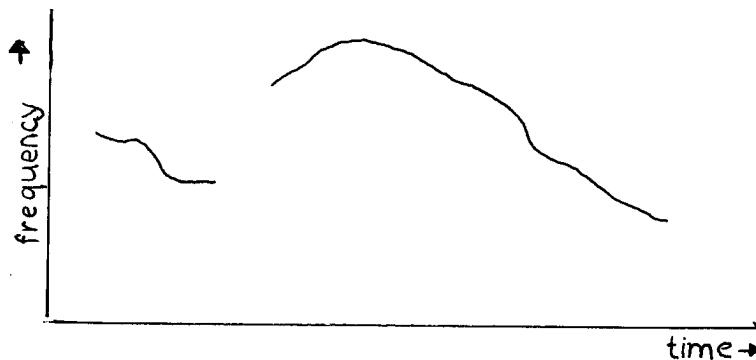


Figure 1.10: F_0 contour for voiced consonants in English (Lea 1973, p. 35).

Lea points out that voiced consonants typically are not fully voiced in English. As in Hausa "voicing may cease during the latter part of voiced obstruents" (p. 34). Hombert also shows a rising curve in the initial portion of the vowel following voiced stops in English. (p. 33) In addition, Hombert provides data for voiced stops in Yoruba. Although Hombert's data show the effect of consonants on high, mid, and low tone syllables, only the high tone data are given here since my data for Hausa are for high tone syllables. Note that in Yoruba, as in English, there is a rise into the vowel following the voiced stops:

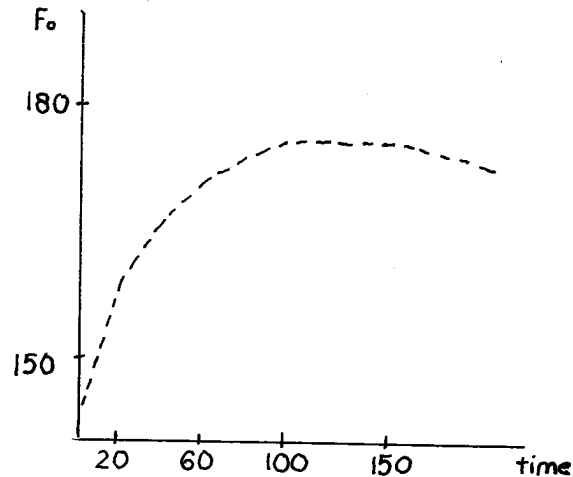


Figure 1.11: F_0 of vowels in Yoruba after voiced stops, high tone. (Hombert, 1975, p. 43).

Hausa voiced stops do not have the "valley" which is characteristic of voiced stops in these other languages. Instead, typically, there is a dip in pitch during the voicing of the consonant, followed by a short onset (50% of the time), followed by a pitch raising transition (75% of the time). The vowel following the voiced stops is at a slightly lower pitch than the vowel preceding the voiced stop:

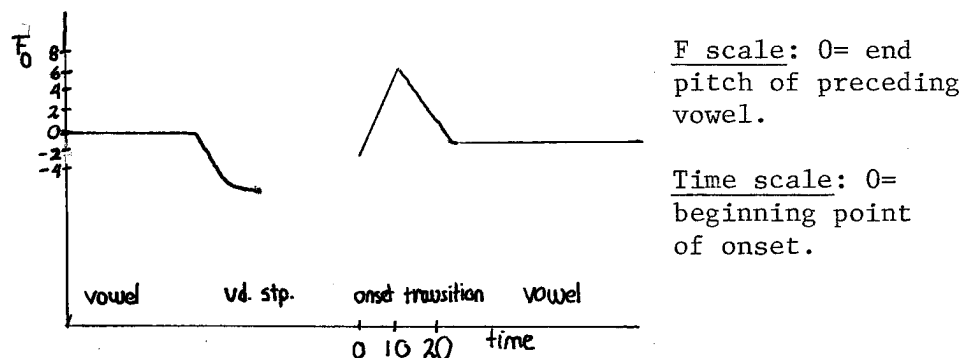


Figure 1.12: F_0 contour for voiced stops in Hausa. The contour represents the averages for voiced stops (29 tokens) which was given in (30).

Gandour (1974) shows a similar contour, short onset, followed by a slightly raised transition in Thai before mid tone (p. 97) and rising tone (p. 98). Hombert found that French voiced stops raised pitch during the stop in 20% of the tokens he examined. He claims that this rise in pitch may be due to lowering of the larynx in order to maintain full voicing throughout the segment. This rapid displacement could result in an increased rate of air flow across the glottis (1975, p. 75). This explanation is not available for Hausa, since voicing is not maintained throughout the majority of the stops.

In this section the voiced stops were found to have effects on the pitch at onset, transition and during the C-vowel. Place of articulation resulted in different effects on pitch. The significance of these effects as perceptual cues for a voicing distinction and the possibilities that they could lead to historical change are discussed in section 1.5.2 since the important distinctions for voiced stops can only be stated in relation to the cues for all the segment types.

1.4.2 Voiceless unaspirated stops (with glottal closure).

In section 1.3.9, it was shown that the Hausa "implosives" are voiceless unaspirated stops, with probable glottal closure. The data obtained for these stops are given in Tables 1.3 and 1.4. These measurements yield the following results:

(25) Results for voiceless unaspirated stops (with glottal closure)

	b	d	both stops
number of <i>tokens</i>	11	10	21
number of <i>onsets</i>	6	5	11
average effect	+3.3 hz	-6.4 hz	-1 hz
average length	13 msec	14 msec	13 msec
number of transitions	10	10	20
average effect	+15.1 hz	+9.1 hz	+12.1 hz
average length	41 msec	34 msec	37 msec
comparison of <u>ga</u> -vowel with <u>C</u> -vowel	-3 hz	-2.1 hz	-2.5 hz

According to the data in (25), the laryngealized bilabial stops raise pitch at onset 3.3 hz (the pitch is higher at onset than the final pitch of the preceding ga-vowel, but the pitch at onset is lower than the pitch of the immediately following transition). The alveolar stops, on the other hand, have onsets which are an average of 6.4 hz lower than the pitch of the preceding ga-vowel. The data in Tables 1.3 and 1.4 provide an explanation for these differences. For the bilabial segment, token eight raises pitch 20 hz while all the other tokens have effects from minus three hz to plus three hz at onset. If token eight is excluded from consideration, the other tokens average out to having no effect on pitch at onset; they average out to zero. Similarly, with the alveolar segment, token two lowers pitch 22 hz, while all the other tokens cluster between minus 4 and plus 8 hz. Without token two,

Table 1.3: Voiceless Unaspirated Stop (glottal closure): b

	<u>ga-vowel</u>	<u>onset</u>	<u>diff</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	98	none	---	none	---	96-94-96	-3
2.	96-100	100	0	111 104 108 98	+11	96/95	-3
3.	100-101	102	+1	110 98	+9	100-102-100	0
4.	103-102	105	+3	121 111	+19	87/97	-5
5.	97-95	92 99	-3	110	+15	97/96	0
6.	94/93	none	---	104 101	+11	88/87/86	-5
7.	95-92	none	---	108 106 101 90 91 92 91	+16	87/86	-6
8.	92-89	109	+20	111 103 105 98 95	+22	91/90/89	-1
9.	95-96	none	---	114 101 103	+18	90/91	-5
10.	95/96	95 96	-1	111 102 97 95 93 96 95	+15	92/91	-4
11.	98-99-96	none	---	111 102 109 101 98 98 100 101	+15	99-94	-1

Table 1.4: Voiceless Unaspirated Stop (glottal closure): \underline{d}

	<u>ga-vowel</u>	<u>onset</u>	<u>diff</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	99-98-100	100	0	101	+1	95-93-98	-4
2.	103-100-102	80 8	-22	111 105 98	+9	96-100	-3
3.	107-103	none	---	116 110 109 102 98 102	+13	100-97-103	-5
4.	100-95	97 103	-8	112 100	+17	97-95-97	-1
5.	97-98	104	-6	112 107 97	+4	95-92-95	-4
7.	94-93	97	+4	104 102	+11	95-87	-2
8.	90-88	none	---	104 97 100 96	+16	90-86-90	-1
9.	99-95	none	---	(526 0 33 92) 102 103	+7	96-92-103	+5
10.	103/101	none	---	(446) 109 101	+9	97-95-97	-4
11.	93-90	none	---	94 94 92 93	+4	91-83-95	-2

(The numbers in the transition column which are in parentheses are taken to reflect high frequency noise and are not considered here to be reliable figures; in these cases the next figure was used as the first pitch period in the transition.)

all the other tokens together have an average of -2 hz at the onset. Averaging all the tokens for the laryngealized stops together, excluding these two extreme tokens, these segments lower pitch an average of 1.1 hz at onset. Because of the wide scatter of onset pitches, and the fact that only half the tokens had onsets, it is probable that the onset measurements are not reliable for these segments.

The laryngealized segments have higher and longer transitions than the voiced stops: they raise pitch twice as high, and last twice as long as the transitions of the voiced stops. The transitions in recordings 2, 7, 8, 9, 10, and 11 of the bilabial tokens, and recordings 3, 8, 9, and 10 of the alveolar tokens have some irregular patterning in the pitch curve in place of the 'plain' falling curve found in the other tokens. These transitions may involve some laryngealization. In addition, note that even though the transition period of these segments is uniformly high, the C-vowel, after the transition, is 2.5 hz lower than the pitch of the preceding *ga*-vowel. These segments raise pitch at transition, but lower pitch further into the vowel. Since creaky voice tends to lower pitch, this finding supports Ladefoged's claim that the laryngealization in these segments is most apparent within the following vowel rather than within the consonant itself.

It is difficult to discuss these findings in relation to what other researchers have reported for other languages in the literature, since the exact phonetic characteristics of the 'implosives' the other researchers discuss is not known. For example, most researchers follow Greenberg in claiming that voicing is expected in laryngealized stops. However, in all previous studies of Hausa (including Greenberg's), the 'implosives' have been claimed to be fully voiced and, as was shown in section 1.3.9, these segments have no voicing. On their hierarchy of tone-raising consonant types, Hyman and Schuh claim that implosives are pitch-raising, in fact, that they raise pitch more than any other segment type. They support their claim that the implosives are pitch raising segments with data from Ngizim. In Ngizim the implosives pattern with the voiceless stops and sonorants in that they allow tone spreading of high tones and block tone spreading of low tones. To support their claim that implosives "have more of a tone raising effect than any other class of consonants", they offer the following evidence: "The first author and John Ohala observed on the pitch extractor in the Phonology Laboratory at the University of California, Berkeley, that the pitch of a vowel shot way up after an implosive consonant. The same vowel rose only slightly after a voiceless obstruent" (p. 110). This evidence is not adequate to support a claim that, universally, implosives have the *greatest* tone raising effect. Greenberg claims that the voiced injective stops have a similar effect on pitch as the voiceless or ejective consonants in that they don't lower pitch and may raise pitch. In discussing work by Haudricourt, Greenberg says that, in Southeast Asian languages, implosives "sometimes ... act partially like voiced and partially like unvoiced, though more like the latter" (1970, p. 133). In my findings the laryngealized stops raise pitch (and thus are similar to the voiceless stops) at transition, but lower pitch (and thus are similar to the voiced stops) in the body of the vowel. Not enough is known about the phonetic properties of the implosives found in other languages, or about their effects on pitch, to make any claims about where

the implosives belong on a universal hierarchy of segment types. These segments will be discussed in relation to all the other Hausa segments in section 1.5.1.

1.4.3 Voiceless Aspirated Stops

The measurements obtained for the voiceless aspirated alveolar and velar stops are given in Tables 1.5 and 1.6. These measurements yield the following results:

(26) Results for the Voiceless Aspirated Stops

	t	k	both stops
number of <i>tokens</i>	10	10	20
length of aspiration	39 msec	49 msec	44 msec
number of <i>transitions</i>	10	10	20
average effect	+8.8 hz	+16.9 hz	+13.1 hz
average length	34 msec	19 msec	23 msec
comparison of <u>ga</u> -vowel with C-vowel	-.2 hz	+2.5 hz	+1.1 hz

The velar stop has a much greater pitch-raising effect at transition than the alveolar stop. This is in accordance with the findings for the voiced stops in section 1.4.1, that is, place of articulation does make a difference in effects on pitch, with those stops which have the smaller oral cavity (the velar stops) having more of a pitch raising effect. There seems to be the following relationship between the pitch effects and the length of aspiration and **transition**:

t	k
lower transition	higher transition
shorter aspiration	longer aspiration
longer transition	shorter transition
lower vowel (after trans)	higher vowel (after trans)

The numerous studies of the effects of voiceless aspirated stops on pitch, particularly the effect of voiceless aspirated stops on pitch in English, all report that voiceless aspirated stops raise **pitch** (see Hombert, 1975, for discussion). The *duration* of these pitch effects varies from language to language. Hombert found that in English the pitch raising effect of voiceless aspirated stops was still evident 100 msec into the vowel. For Thai, Gandour found that the **voiceless aspirated stops raise pitch** during the first 17 msec in high tone syllables and 30 msec in low tone syllables. In Hausa, the velar voiceless aspirated stop results in a vowel 2.5 hz higher than the preceding ga-vowel, but the voiceless aspirated alveolar stop does not have this pitch raising effect in the body of the vowel: the body of the C-vowel after transition, in the alveolar stops, is 2 hz lower than the ga-vowel.

Table 1.5: Voiceless Aspirated Stop: t

<u>t</u>	<u>ga-vowel</u>	<u>length of asp</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	97-95	40 msec	(180) 109 98 97 98	+7	96 94 96	-1
2.	103	30 msec	(345 72)	---	109-100	+1
4.	100-102-104	40 msec	107 104	+3	100-97-100	-3
5.	100-98	50 msec	105	+7	100-97-100	0
6.	103-105	50 msec	107 106 105 106	+2	102-104	-1
7.	101/100	50 msec	120 115 106 103 103 103	+20	100-97-100	-1
8.	90/91	40 msec	(214) 103 98	+12	90-86-88	-2
9.	96/97	10 msec	(526 109 179) 105 105	+8	101-110	+9
10.	95-92	40 msec	107 103 96	+15	92-89-93	-2
11.	101/100/102	40 msec	(192) 108 104	+6	101-97-100	-2

Table 1.6: Voiceless Aspirated Stop: k

<u>k</u>	<u>fa-vowel</u>	<u>length of asp</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	96-100	20 msec	120	+20	102/103/102	+5
2.	101	40 msec	(327)	+20	103	+2
3.	104-106	50 msec	121 111 106 105	+18	107/108/106	+2
4.	101-98	50 msec	124 111	+15	103-100-103	+2
5.	100-97	60 msec	113	+11	100-99-103	+3
6.	98/96	50 msec	108	+25	100-96-98	+1
7.	105-103	60 msec	121 106	+16	106-104-108	+2
8.	95-91	50 msec	199 111	+18	95-88-95	+3
10.	96	50 msec	108 101	+17	98-96-100	+2
11.	102-104	60 msec	113 105	+9	107-105-108	+3
			113			

As shown above, the longer the aspiration the higher the pitch at transition (and, perhaps, the higher the C-vowel). Hombert cites data from Korean, French, and English which supports this correlation (1975, pp. 46, 70-75). This correlation between aspiration and high fundamental frequency will be discussed again in the sections on the voiceless fricative (1.4.6) and the affricate (1.4.7) as well as in the final section where the findings for all the segments are compared.

1.4.4 Ejective Stop

The pitch measurements for the velar ejective stop, $\underset{k}{k}$, are given in table 1.7. These measurements yield the following results:

(27) Results for the ejective stop

	$\underset{k}{k}$
number of <i>tokens</i>	11
length of <i>aspiration</i>	67 msec
number of <i>transitions</i>	11
average effect	+9.6 hz
average length	31 msec
comparison of <u>ga</u> -vowel and C-vowel	-.90 hz

Five of the tokens raise pitch a lot at transition (tokens 4, 5, 6, 8, 9, and 10) and six of the tokens raise pitch a lot less (tokens 1, 2, 3, 5, 7, and 11). The amount of raising does not correlate well with length of transition, or length of aspiration probably because there is laryngealized voicing during these portions of the utterance. (Two recordings have no aspiration, one raises pitch 23 hz and the other does not raise pitch at all). I would expect this kind of variation in the articulation of this segment, because its articulation is quite complex and might be simplified in rapid speech. Five of the tokens have an irregular pitch pattern during the transition. This type of pattern was seen in the voiceless unaspirated laryngealized stops. It probably correlates with the glottalic component of the consonant. Greenberg notes that, with ejectives, "as is often pointed out in the phonetic literature, the glottal occlusion is normally released after the oral occlusion" (1970, p. 154). In these tokens with long, irregular transitions, it is probable that the velar closure is released after a short period of voicelessness -- its release is signaled by the burst of noise at the start of the period of aspiration; the glottal closure, on the other hand, is released just at onset of the vowel and is followed by a period of laryngealized voicing during the initial portion of the vowel. With the other tokens both the velar and the glottal closures are released simultaneously and there is a period of creaky voice before onset of the vowel.

Greenberg, in his survey of glottalic consonants, claims that the ejective groups with the voiceless and implosives in that it "fails to lower pitch" (p. 132). Hombert claims that ejectives "seem to be

Table 1.7: Ejective: k

<u>k</u>	<u>ea-vowel</u>	<u>length of asp</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	101-99	70 msec	101	+2	94-100	-4
2.	101-96	60 msec	97 96 97 98 96	+1	97-100	0
3.	102-100	80 msec	102 102 98 98	+2	102/103/104/100	+1
4.	100-95	70 msec	112 4	+12	93/91/94-95	-4
5.	90-93	60 msec	(129) 101	+8	12/93/95/96/97	+2
6.	98-97	90 msec	115 99 95 99 102 99	+18	99-94-97	-1
7.	95-92	50 msec	95 0 94 93	+3	98/90/93/91	-3
8.	93-95-93-92	none	115 111	+23	92/89/90/91	-3
9.	90/91	60 msec	109 8 95 109 98	+18	92-100	+5
10.	95-93	70 msec	112 99	+19	92-96	0
11.	92/93	none	93 90	0	88-92	-3

'neutral' with regard to lowering or raising fundamental frequency of neighboring vowels" (1975, p. 12). Because of the wide scatter of pitch at transition (from zero to twenty-three hz), and because of the lack of effect on the following vowel (-.90 hz), it would seem that pitch height at the beginning of transition, or during the C-vowel would not serve as an effective perceptual cue to distinguish ejectives from other consonants. Rather, the long period of aspiration combined with irregular pitch patterns during the transition period are distinctive to this segment.

1.4.5 Fricative

The measurements for the voiceless fricative, s, are given in Table 1.8. These measurements yield the following results:

(28) Results for the Voiceless Fricative

	s
number of <i>tokens</i>	10
number of <i>transitions</i>	10
average effect	+23.3 hz
average length	29 msec
comparison of <u>ga</u> -vowel with C-vowel	-2.8 hz

Hyman and Schuh do not differentiate between obstruents and fricatives on their hierarchy of segment types, but they predict that there will probably be differences between the pitch effects of stops and fricatives (1974, p. 110). The Hausa voiceless alveolar fricative raises pitch much more than the voiceless aspirated alveolar stop at transition (t raises pitch 8.8 hz; the transition of the stop lasts longer, 3¹/₄ msec).

Gandour found that in Thai, s raises pitch during the initial portion of the vowel. However, the fricative raises pitch less than the voiceless unaspirated and voiceless aspirated stops; except before rising tone where s raises pitch more than the voiceless aspirated stops (1974, p. 103). Lea found that in English the voicing distinction made a difference in what kinds of pitch effects the fricative would have on the following vowel. Voiced fricatives had a rise into the following vowel, like the voiced obstruents, and voiceless fricatives had a fall into the following vowel, like the voiceless obstruents. Although the Hausa voiced fricative, z, was not included among the segments which were systematically analyzed for this experiment, the few recordings which were made of this segment show that voicing results in different pitch effects on the following vowel than what was found in the results for the voiceless fricative. Figure 1.9 is a recording of the sentence sun zauna, with the voiceless fricative in initial position, and the voiced fricative in intervocalic position:

Table 1.8: Voiceless Fricative: s

<u>s</u>	<u>ga-vowel</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	98/96/97	116 109 101	+19	97/98-100	+1
2.	100-95	109 103	+13	99/97	+1
4.	102-96	122 110 102	+26	98-95-100	-2
5.	101-92	119 106 98	+25	95-91-95	-3
6.	96-92	(144) 121 100	+29	90-86-90	-6
7.	100-95	120 108 97	+25	92-87-93	-7
8.	91/89/90	123 103 91	+33	88-85-88	-3
9.	91/90/92	115 101 101	+23	92-89-92	-1
10.	97/98/95/96	117 105 97	+21	92/95	-3
11.	99-95-98	117 106 98	+19	95-90	-5

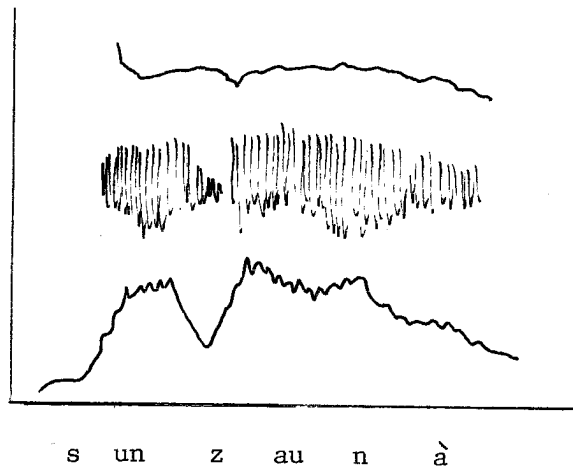


Figure 1.13: Sun zaunà 'They sat down'

Note that there is a fall into the vowel after the voiceless fricative, while the voiced fricative causes a dip in pitch during the fricative, and the initial portion of the following vowel does not fall. Thus, the voicing distinction influences the pitch effects of the fricatives more than any other factor; but the *manner* of articulation also predicts very different effects on the pitch of the following vowel; the fricative raises pitch nearly three times higher than the stop at the same point of articulation when both segments are voiceless.

1.4.6 Ejective Fricatives

The measurements for the glottalized fricative, ts, are given in Table 1.9. The tokens seem to fall into two patterns. Recordings 1, 2, 8, and 10 do not raise pitch at transition. The vowel following the consonantal segment in these recordings begins at a pitch which is slightly higher than the pitch of the rest of the vowel, but still is lower than or very close in pitch to the last pitch of the preceding ga-vowel. The analysis of these tokens is given in Pattern A, below. The other pattern is very similar to the patterns found for the voiceless fricative, s. Recordings 4, 5, 7, 9, and 11 raise pitch at transition to a pitch considerably higher than the last pitch of the ga-vowel. These tokens are analyzed as Pattern B, below.

(29) Results for the Glottalized Fricative

<u>Pattern A</u>	ts
number of <i>tokens</i>	4
number of <i>transitions</i>	4
average effect	+1.5 hz
average length	17 msec
comparison of <u>ga</u> -vowel with C-vowel	-4.5 hz

<u>Pattern B</u>	ts
number of <i>tokens</i>	5
number of <i>transitions</i>	5
average effect	+21 hz
average length	24 msec
comparison of <u>ga</u> -vowel with C-vowel	-2.4 hz

Notice that in Pattern A, the vowel following the segment is at a considerably lower pitch than the vowel following the segment in Pattern B, both at transition, and during the body of the vowel. From the distribution of the tokens for the glottalized fricative it seems as though my informant has two possible articulation patterns for this segment. Pattern A probably represents a pattern of articulatory timing where the glottal occlusion is released with laryngealized voicing during the friction of the s, thus lowering the pitch at transition. Pattern B probably represents an articulatory pattern where during the friction noise of the s there is no longer a (lowering) glottalic component, and, thus at onset of the following vowel, there are pitch effects which are very similar to those found for the 'plain' alveolar fricative.

As far as I know there is no specific mention of the pitch effects of glottalized fricatives in the literature on consonant types and tones.

Table 1.9: Glottalized Fricative: ts

<u>ts</u>	<u>ga-vowel</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	105-100	102 101	+2	95-96/97/98	-6
2.	102-100	99	-1	95/97/96	-5
4.	103-97	119 106	+22	97/95/96	-4
5.	97-95/96	121 99 87 90	+25	96/97/95/93	0
7.	103-101	116 115 101 95	+15	98/100	-2
8.	90-89	92 88 90	+3	89/86	-2
9.	91/92/90	115	+25	90/91/88	-2
10.	103-99	101	+2	96/95/97	-5
11.	94-93	114 96	+21	92/90/91/89	-3

1.4.7 Affricate

The measurements for the voiceless affricate, c, are given in Table 1.10. These measurements yield the following results:

(30) Results for the Voiceless Affricate

c	
number of <i>tokens</i>	10
length of <i>aspiration</i>	71 msec
number of <i>transitions</i>	10
average effect	19.1 hz
average length	24 msec
comparison of <u>ga</u> -vowel with C-vowel	-2 hz

The voiceless affricates have a short, high transition. They raise pitch higher than the voiceless alveolar stop (t raises pitch 8.8 hz) but the transition is shorter (the average transition for t lasts 34 msec). On the other hand the voiceless alveolar affricates raise pitch less at transition than the voiceless alveolar fricative (s raises pitch 23.3 hz), and, again, the transition period of the affricate is slightly shorter (the transition periods for s last an average of 29 msec). During the C-vowel, c resembles s (s lowers pitch 2.8 hz during the C-vowel, while t lowers pitch only .2 hz). C has twice as long a period of aspiration as the voiceless alveolar stop (aspiration lasts 39 msec for t). Thus, it seems that manner of articulation causes the affricate to raise pitch higher than the stops, but less than the fricatives. Lea (1973) has data for English for both the voiced and voiceless alveolar affricates. His data show that the voiced fricative lowers pitch slightly, and the voiceless affricate raises pitch more than any other segment except k. In the few recordings in my data of the voiced Hausa affricate, j, there is no rise in pitch after this segment, rather, there is a dip in pitch during the segment, and the following vowel is at the same height as the vowel which preceded the segment.

The voicing distinction is the most important factor in determining what effect the affricates have on pitch. Manner of articulation is also important: the voiceless affricate raises pitch at transition more than the voiceless stops, but less than the voiceless fricative.

1.4.8 Laryngealized Glottal Approximant

The pitch measurements for the laryngealized glottal approximant ʔ, are given in Table 1.11. The measurements yield the following results:

Table 1.10: Affricate: c

<u>c</u>	<u>ga-vowel</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	102-99	114 109	+16	103-100	+1
2.	101-102	114 109	+12	103-97	-1
4.	100-96	110 110 102	+14	98/100/97	0
5.	100-95	107 107 101	+12	97-99-92	-1
6.	93/94	117 104 94	+23	91-88	-4
7.	98-95	116 103 96	+21	91/93	-4
8.	91/92/90	119 101	+29	92-87/86	-3
9.	93-92	113 104	+21	93-87-92	-2
10.	95	116 103	+21	95-88	-4
11.	96/95	117 104	+22	97-90-92	-2

Table 1.11: Laryngealized Glottal Approximant: ?

	<u>ga-vowel</u>	<u>onset</u>	<u>diff</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	99-98	none	---	none	---	92-100	-2
2.	101-100	92	-8	none	---	96/98/99/97	-3
3.	110-106	91 94 95	-17		---	100-104	-6
4.	104-102	none	---	none	---	89-103	-7
5.	97-95	85	-10	none	---	90-99	-2
6.	101-98	83 86	-15	none	---	91-99	-4
9.	100-96	none	---	none	---	90/88	-9
10.	104-105	76 80 89 90	-29	none	---	98-103	-4
11.	108-106	74 88	-32	none	---	92-102	-10

(31) Results for Laryngealized Glottal Approximant

	?
number of <i>tokens</i>	9
number of <i>onsets</i>	6
average effect	-18.5 hz
average length	21 msec
comparison of <i>ga</i> -vowel with C-vowel	-5.2 hz

This is the only Hausa segment which results in a unique contour during the C-vowel; the vowels immediately following the glottalized approximant (with one exception) have a rising contour. Most of the tokens also have a long, low, rising onset. This contour is very similar to that found for syllables which begin with nasals or glides when they occur in utterance-initial position.

With reference to the effects on pitch of glottal stop which have been reported elsewhere in the literature, Hombert studied the effects of *postvocalic* glottal stop and *h* on the pitch of *preceding* vowels. He found that glottal stop consistently is preceded by a vowel with a rising contour; the rise begins at least 100 msec before the onset of the glottal stop. [*h*] causes a fall in the pitch of the preceding vowel for approximately 50 msec before onset of the glide. He claims, along with Haudricourt, that these effects are the result of increased tension of the vocal cords during the glottal stop, and decreased tension of the vocal cords during the articulation of the glide. Ohala (1970) claims that the decreased vocal cord tension during the *h* is due to a brief "period of inhibition of the lateral cricothyroid muscles" (Hombert, p. 53). An examination of the pitch measurements for the preceding vowels in Hausa shows that there is predictable falling contour to the *ga*-vowel when followed by a laryngealized approximant (see Table 1.11). This finding provides additional evidence to that discussed in Section 1.3.11 that this segment is an *approximant*, not a stop. It might be predicted from Hombert's findings that pitch would fall during the initial portion of *postvocalic* vowels following glottal stop, and rise during the initial portion of *postvocalic* vowels following *h*. Greenberg (1970) claims that glottal stop "has the same tonal effects as the voiced ejective stops" (p. 133) they are not pitch-lowering and thus group with the voiceless stops and ejectives. Lea, in his analysis of the effects of English consonants on following vowels, groups the glottal stop with the voiced segments, and shows that it has pitch-lowering effects similar to all the other voiced segments (p. 51). What seems to be the primary factor in determining what effect glottal stop will have on the following vowel is whether the vocal cords are completely closed, or not. The Hausa glottal stop in intervocalic position, and the English glottal stop, lower pitch because the vocal cords are not completely closed, and they are still able to vibrate. The four recordings of the Hausa

glottal stop in utterance-initial position where there are no vibrations because the vocal cords are completely closed, all have a high-pitched transition period, followed by a fall lasting an average of 55 msec, followed by a rise during the C-vowel. Looking through data gathered for other purposes, about half of the utterance initial glottal stops had the rising contour associated with voiced stops, and half had the high transition period associated with voiceless stops. Position within the utterance then, determines whether the segment has a partially vibrating or a closed glottis and the segment has very different effects depending on this distinction. The differences in the literature on whether glottal stops should be associated with a pitch increase or a pitch decrease probably arise because of differences in what are called glottal stops. The label 'glottal stop' is sometimes applied to segments in which the glottis is tightly closed (and therefore the vocal cords are tense and the pitch tends to be raised) and sometimes to the segments that have creaky voice (in which the vocal cords are short, without longitudinal tension, so that the pitch tends to be lowered). Both these variants occur in Hausa; a 'true' glottal stop with glottal closure may occur utterance initially or after pause, and the geminate is always articulated with complete glottal closure. The creaky voice variant occurs when a vowel precedes, either within the word, or across word boundaries.

The significance of the pitch effects of this segment as perceptual cues, and its effect on historical change will be discussed in Section 1.5.1.

1.4.9 Glottalized Glide

The measurements obtained for the glottalized glide, 'y, are shown in Table 1.12. These measurements yield the following results:

(32) Results for Glottalized Glide

	<u>'y</u>
number of <i>tokens</i>	8
number of <i>onsets</i>	4
average effect	-.50 hz
average length	15 msec
number of <i>transitions</i>	4
average effect	+12.2 hz
average length	12 msec
comparison of <i>ga</i> -vowel with C-vowel	-2 hz

There is a lot of variation in the pitch patterns of these tokens. Only half of the tokens have onsets, and only half have transitions. The same kind of variation was found with the ejective stop and the ejective fricative; it is probably due to the fact that the articulation of these segments is particularly complex. Note that those tokens which have

Table 1.12: Glottalized Glide: 'y

	<u>ga-vowel</u>	<u>onset</u>	<u>diff</u>	<u>transition</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	100-97	105	+8	108	+11	100-95	-1
2.	101-99	none	---	112	+13	103-95	-1
3.	106-104	none	---	113 113	+9	107-100	-2
4.	102-103	95 96	-8	none	---	100-96-100	-4
5.	99-96	none	---	none	---	96-92	-8
7.	97-93	91	+2	none	---	95-91	-2
9.	99-92	92 96	0	none	---	97-95	+1
10.	101/103/100	none	---	116	+16	103/101	+1

transitions do not have pitch lowering onsets (see recordings 1, 2, 3, and 10) and that those tokens which do have onsets which begin at the same pitch as the final pitch of the ga-vowel, or begin at a lower pitch, do not have pitch raising transitions (recordings 4, 5, 7, and 9). Probably this variation is due to the timing in the release of the glottal occlusion. If the glottal stop is released during the glide, then there is pitch lowering laryngealized voicing before onset of the C-vowel. If both the glide and the glottal stop are released at the same time, then the initial portion of the C-vowel is immediately preceded by a glottal stop, and the initial portion of the vowel will have a high-pitched transition, just like the vowels which follow the voiceless stops.

1.4.10 Glide and Nasal

It was very difficult to segment the utterances with the voiced glide, y. The pitches throughout the tokens are very similar, with no clear-cut changes in pitch and intensity which could be used for segmentation. My measurements are based on the results of the following strategies. I had found that the ga-vowel lasted an average of 60 msec. After the release of the g in each token, the next 6-7 measurements (60-70 msec) were taken to be the ga-vowel. The next 70-80 msec were taken to be the glide, and all following pitches until the dip in pitch and intensity for the r were considered to be the C-vowel. Since these strategies cannot be completely accurate no claims are made about onset or transition points. What was compared was the difference between the average pitch during the glide and the average pitch during the ga-vowel, and the difference between the average pitch during the glide and the average pitch during the C-vowel. The measurements are given in Table 1.13.

(33) Results for y

	<u>y</u>
number of <i>tokens</i>	11
average pitch of glide	-.72 hz
average pitch of C-vowel	-.72 hz

The strategies used for the glides were also used for the nasal, m. In five out of ten tokens the initial portion of the C-vowel was higher than the pitch during the nasal. The pitch measurements given in Table 1.13 resulted in the measurements in (34):

(34) Results for m

	<u>m</u>
number of <i>tokens</i>	9
average pitch of nasal	-1 hz
average pitch of C-vowel	+.33 hz

Table 1.13: Glide and Nasal: y and m

<u>y</u>	<u>ga-vowel</u>	<u>pitch during glide</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	100/102	101/102	+1	103-101/102	+1
2.	104-103	103	0	103-100	-1
3.	105/104	104-102	-1	103-102	-2
4.	100/98	97-98	-2	100/98	0
5.	100/101/103	102/100/101	-1	100/99/98	-2
6.	96/97/94	95/96	-1	93/95/94	-1
7.	97-95	95-93	-2	95	-1
8.	97/96	96/95	-1	95/96	-1
9.	98/97	96/97	-1	97/96	0
10.	97/98/99	97/99	0	99	+1
11.	99/98	98	0	97/96	-2

<u>m</u>	<u>ga-vowel</u>	<u>pitch during glide</u>	<u>diff</u>	<u>C-vowel</u>	<u>diff</u>
1.	97/96	95/96	-1	98 97/96	1
2.	101/100	97/99	-2	97/99	0
3.	98/97	95 98/97	0	98/95/97/94	-1
4.	97/95	94 98-97/96	1	97/95/94	-1
6.	98-93	93/92/91	-3	97/95/94	3
8.	95-93	93/92/91	-1	92/93/91	0
9.	92-89	86-90	-2	91/90/89	2
10.	90/89	88/90/89	0	89/90	0
11.	90/91	88/90	-1	89 88/87	-1

The nasal segment seems to cause a very slight dip in pitch, and the following vowel is not lower than the preceding vowel.

Hyman and Schuh do not place nasals or glides per se, on their hierarchy, but they claim that "it is likely that nasals may be closer to being of a tone lowering nature than, say, liquids or glides or vowels" (p. 110). Lea in his study of English segments shows the nasal m lowering pitch more than the glides j and w; Lea's data are supportive evidence for Hyman and Schuh's predictions. A diagram in Gandour (1974) shows that the nasal n has a very slight raising effect just after vowel onset with mid tones (p. 97). There is a slightly higher-pitched onset after the alveolar nasal before rising tone (p. 98) and low tone (p. 108). This slightly raised pitch following nasals is contrary to what Hyman and Schuh predicted, as is my Hausa data which show that although there is a dip during the nasal segment itself, the following vowel is .33 hz *higher* than the preceding ga-vowel, while the glide is followed by a vowel which is .72 hz *lower* than the preceding ga-vowel.

1.5 Comparison of the Results

1.5.1 Comparison of the Results for the Individual Segments.

In this section the findings for all of the individual segments are compared. The pitch curves for all the segments are presented, and the hierarchies of segmental effects that result from the analysis of the comparative effects are also presented. Next, these segmental features which determine the kinds of pitch effects a given segment will have are analyzed. The rest of this section is devoted to a discussion of the interrelationships between these segmental features and the kinds of pitch effects which were found.

In examining those pitch effects which could be attributed to segmental influence several questions must be asked. First, and most obvious, which changes in fundamental frequency can be attributed to consonantal effects, and how do the effects of the individual segments differ from each other? Second, what are the patterns of these perturbations -- do they occur during the onset, transition, or throughout the entire vowel following the consonantal segment. How do the patterns of the individual segments differ? It was found in the preceding sections that some segments have an effect on pitch at transition only, while other segments may have an effect prior to transition or during the C-vowel as a whole. Third, how long do the pitch effects last? All three of these questions must be discussed relative to each other, if the relative importance of the pitch effects is to be determined.

In Figure 1.14 the pitch curves of all the individual segments are graphed. Each curve represents the average pitch effects for all the tokens of each segment type during each section which was analyzed. Since all pitch effects were determined relative to the vowel preceding the consonantal segment, the ga-vowel, that vowel is represented as zero hz on the vertical axis (labeled F_0). Changes in pitch are represented as either plus or minus deviations from that pitch. The length of the perturbations can be found on the time line, the horizontal axis. Here, zero msec is taken to be the initial point of the

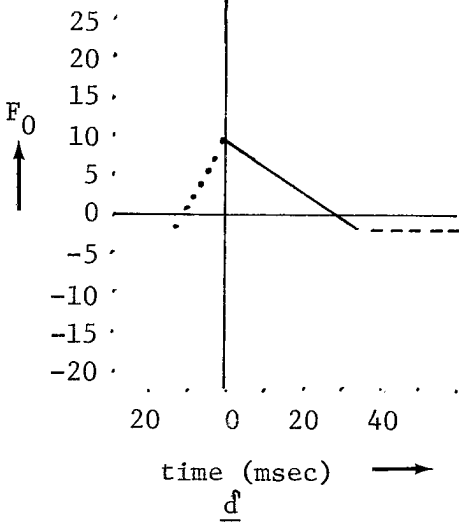
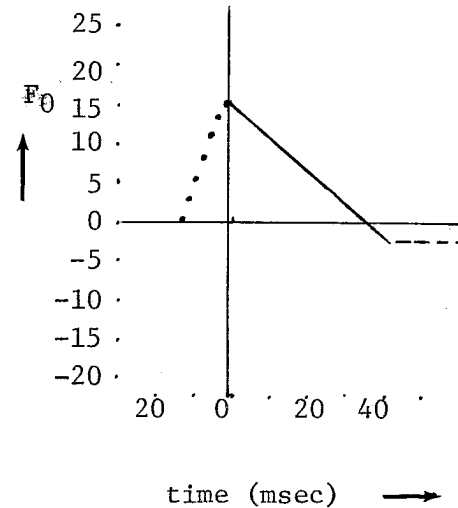
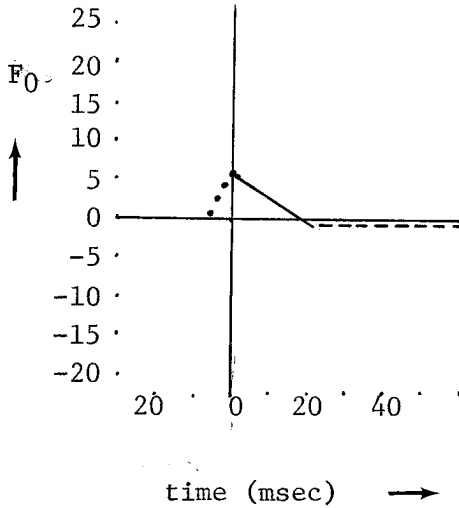
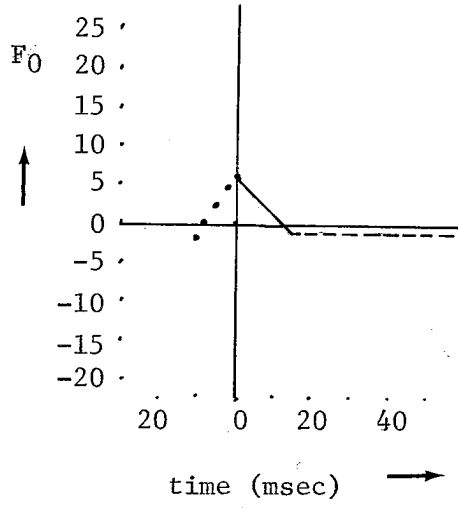
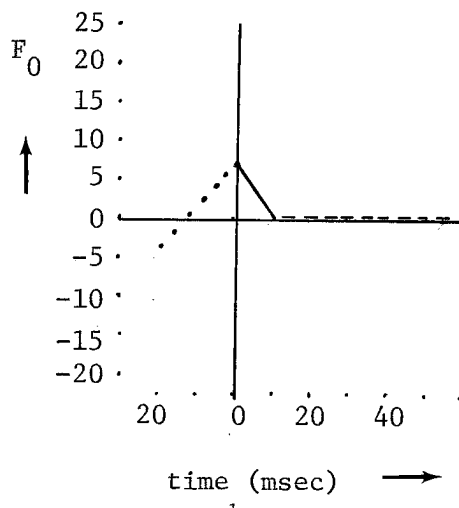


Figure 1.14: Pitch Curves for Segments.

- onset
- transition
- C-vowel

Vertical Coordinate: F_0
 0 Hz: pitch of V preceding the consonantal segment.
Horizontal Coordinate: time
 0 msec: the approximate time of the initial point of the V following the consonantal segment.

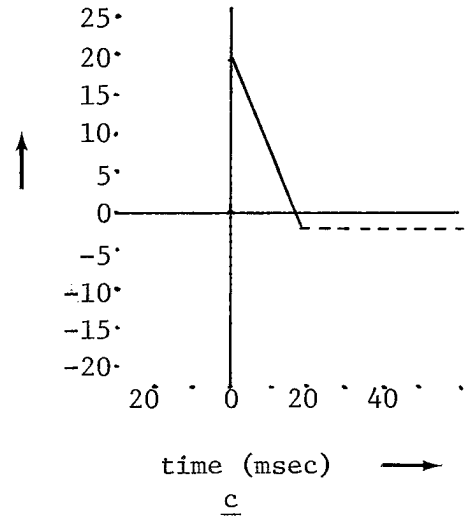
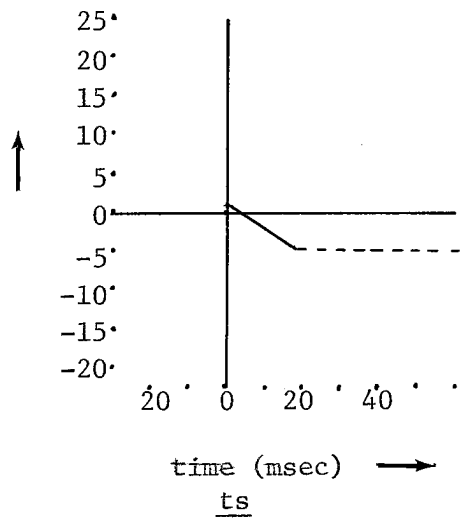
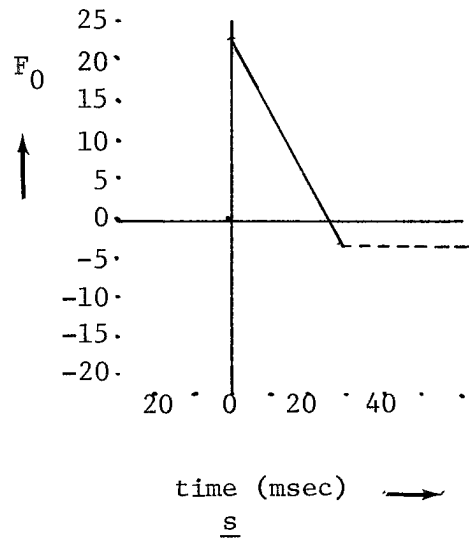
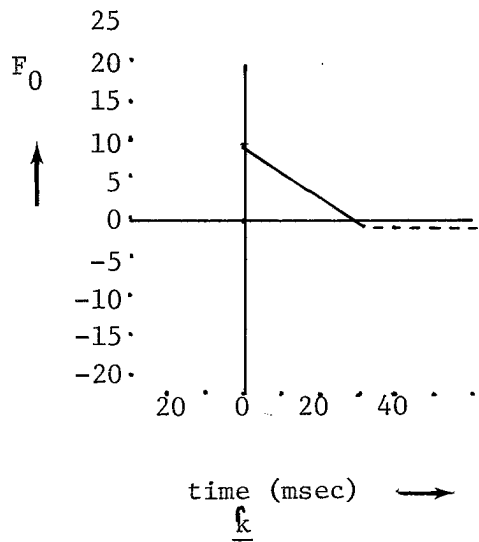
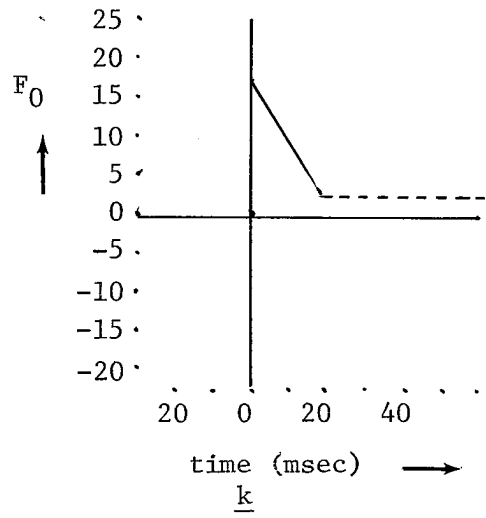
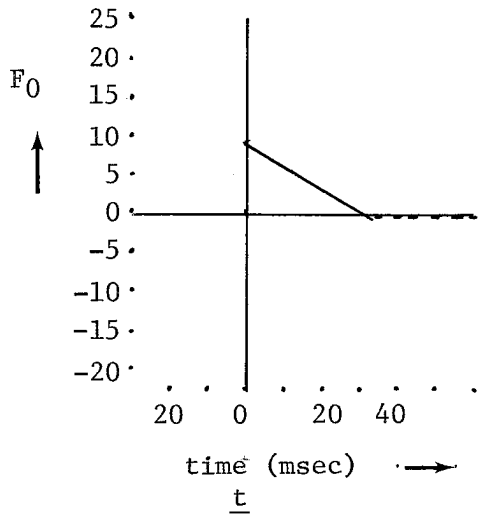


Figure 1.14 (contd.)

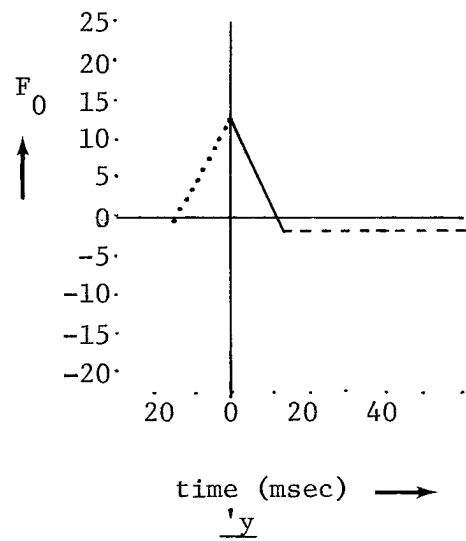
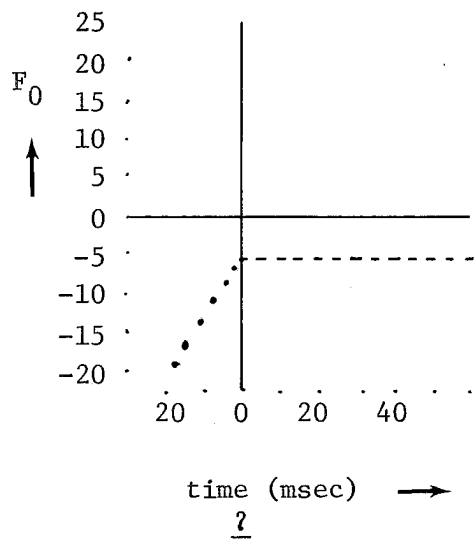


Figure 1.14 (contd.)

vowel following the consonantal segment (the C-vowel). Again, it should be pointed out that such fine segmentation, of the consonant and the following vowel is not really possible, so the zero point on the time scale cannot be absolutely accurate. Notice that the time scale is measured backwards from the zero point, since the length of the onset is measured in number of msec before the initial point of the C-vowel. All four sections which were analyzed for the experiment are represented on these graphs. The pitch of the ga-vowel is the zero line on the fundamental frequency scale, the onset is the dotted line preceding the zero on the time scale, the transition is the solid line immediately following the vowel onset, and the C-vowel is the dashed line. Thus, b has an onset which lasts 18 msec and starts at a pitch of -3.4 hz, followed by a transition that lasts 10 msec and falls from 6.6 hz, followed by a C-vowel which is .33 hz higher than the pitch of the ga-vowel. These pitch measurements result in the hierarchies presented in Table 1.14. In Table 1.14 hierarchies for each section are presented separately; note that the hierarchies for the different portions of the utterance differ. For example, although s has the greatest pitch-raising effect at transition, the vowel following this segment is relatively low on the C-vowel hierarchy, *lowering* pitch 2.8 hz. It is also clear from these hierarchies that not all tokens of a single segment type had the same pattern of pitch effect; for example, some tokens of the voiced bilabial stops had onsets, while others did not. Length hierarchies are also provided for each section of each segment.

From these findings, and the discussions in Sections 1.4.1 to 1.4.10, it is obvious that certain segmental features can be factored out which determine what effects the segments will have. These factors include:

voicing
manner of articulation
amount of aspiration and affrication
place of articulation

The remainder of this section is devoted to a discussion of the interrelationships between these segmental features and the kinds of pitch effects which were found for all the segments at each section of the utterance; onset, transition and C-vowel.

Only half of the segment types had *onsets*, and of the segment types which did have onsets, only about half of the tokens had onsets; 34 tokens out of a total 122 tokens had onsets. *Voicing* is the primary factor influencing whether a segment will have a pitch lowering onset; all the voiced segments had some tokens with onsets, and the voiceless laryngealized stops, b and d, which closely resemble the voiced stops at release, also had short on-gliding onsets at release. But voicing does not guarantee that a segment will have an onset; whether or not the segment is fully voiced throughout its articulation also makes a difference. Of the voiced stops, which were often not fully voiced, only 15 out of 29 tokens had onsets. The pre-requisite for a pitch-lowering onset seems to be that the segment be voiced immediately prior to transition, while the glottalic adjustments are being made for the

tone on the following vowel; the pitch rises while the adjustment is made. *Manner of articulation* also makes a difference. The glottal approximant, the only voiced consonant which was not a stop which was systematically analyzed, had the most pitch-lowering effect at onset, lowering pitch much more than the stops. *Place of articulation* also affects whether a segment will have a pitch-lowering onset (by affecting duration of voicing). Of the voiced stops, the velar voiced stop, with the smallest oral cavity had the fewest tokens with onsets (and was least voiced) having four onsets out of ten tokens, while the bilabial voiced stop, with a larger oral cavity, had seven tokens with onsets out of a total of nine tokens. If there is a glottalic component, however, as with b and d, the bilabial and alveolar closures no longer have the same effect; thus, the bilabial laryngealized stop does not have a pitch lowering effect at onset. At onset, then, the amount of pitch lowering correlates with the following factors, in order of importance: *voicing*, *manner of articulation*, *glottalic component* and *place of articulation*. *Length* of onset should also be taken into account. It is difficult, with the length hierarchy given in Table 1.14, to factor out those segmental features which effect length of onset.

There is a better distribution within the corpus of segments with *transitions*-- 101 tokens out of a total of 122 tokens had transitions. With the exception of the glottal approximant, the nasal and the glide, all the segments had some pitch raising effect at transition. The *voicing* distinction was the primary factor affecting pitch at transition as it was with onsets: the eight segments which are the highest on the hierarchy of pitch-raising effects are all voiceless, and their voiced counterparts do not raise pitch to the same extent. *Manner* of articulation was the second most influential segmental feature and manner forms a sub-hierarchy within those segments which have the greatest pitch raising effect. If x > y then x raises pitch more than y -- with this definition, fricatives > affricates > voiceless aspirated > voiceless unaspirated (with glottal closure) > ejectives. *Place* is also a determining segmental feature. For example, the voiceless velar stop raises pitch more than the voiceless alveolar stop. Again, co-articulation with glottal occlusion influences pitch effects at transition; three segments, b, d, and 'y have a glottal component which makes them voiceless and they raise pitch more than their non-glottalized counterparts, b, d, and y. (See Section 1.4.10 for pitch effects of y.) The glottalic component has the opposite effect on the ejectives, k and ts, it prevents the pitch-raising aspiration and affrication which usually accompanies k and s, thereby lowering pitch at transition. Another possible explanation for the lower pitch effects of these segments is that there is some creaky voice just at transition; this would tend to lower pitch. That it is the glottalic component that has a pitch lowering effect with the ejectives can be shown by examining the pitch effects of the two patterns which were found for the ejective ts. In Pattern A, where the glottal closure was released immediately prior to the beginning of the C-vowel, the segment raised pitch only 1.5 hz at transition. In Pattern B, where the glottalic occlusion was released prior to the end of the affrication, the same pitch effects were found

for the ejective fricative as were found for the 'plain' voiceless fricative, s; s raised pitch 23.3 hz, while Pattern B of ts raised pitch 21 hz. It should be emphasized here, however, that the ejectives have quite a different manner of articulation from that of the other glottalized stops (see section 1.3.2), and the pitch effects of the ejectives must necessarily correlate with these differences.

It is difficult to factor out the segmental features which affect *length* of transition. Glottalized stops, with the exception of the glottalized 'y, have long transitions. In section 1.4.3 it was pointed out that if a segment is accompanied by a long period of aspiration the transition period is shorter. The voiceless alveolar stop, t, has a very short period of aspiration, and a long transition, while the voiceless velar stop, k, has a long period of aspiration and, as can be seen in Table 1.15, a short transition.

With reference to pitch effects on the third section which was analyzed, the C-vowel, one additional factor, beside the segmental factors which have been discussed above, must be discussed. That factor is *intonational* lowering. In Chapter II, section 2.3, a rule of intonational lowering will be introduced which formalizes the finding that in Hausa, when sequences of two or more like tones occur, the pitch of each syllable in the sequence is realized at a pitch which is slightly lower than the preceding like-tone syllable. In the corpus which was set up to test this rule it was found that this rule applied a total of 75 times out of 90 times that the structural description was met. To factor out intonational lowering from the segmental pitch effects within the corpus being examined in this chapter the following strategy was used. The pitch effects for all the tokens during the C-vowel were totaled and divided by the total number of tokens; an average lowering of 1.9 hz was found -- this average lowering was taken to be intonational lowering. Based on this strategy the segmental effects on pitch during the C-vowel were found to be:

Table 1.15 Pitch effects on C-vowel taking intonational effects into account.

Raising	k	+2.5	hz
	b	+.33	hz
	t	-.20	hz
Raising ?	g	-.60	hz
	d	-.80	hz
	k	-.90	hz
No effect	'y	-2	hz
	c	-2	hz
	d	-2.1	hz
Lowering	s	-2.8	hz
	b	-3	hz
	ts	-4.5	hz
	?	-5.2	hz

The boundaries of the categories of effects are questionable, of course. It is clear that k, b, and t raise pitch but it is not clear where to draw the line among the next three segments g, d, and k. Similarly, it is clear that 'y, c and d have no effect on pitch, but it is not clear whether or not s lowers pitch. From the hierarchy above it can be determined that voiceless stops have the greatest pitch-raising effects during C-vowel, including those stops which, although they are voiced during the initial portion of the segment, are voiceless just prior to transition. The lower end of the hierarchy is more random. It is difficult to factor out which segmental features cause s, b and ts to lower pitch. The glottal approximant lowers pitch the most, perhaps because it is articulated with creaky voice.

Hombert (1975) notes that "the duration of the perturbations caused by prevocalic consonants on the fundamental frequency of vowels seems to be shorter in a tone language such as Yoruba than in non-tonal language such as English." This is because "there is a tendency in tone languages to actively minimize the intrinsic effects of prevocalic consonants -- probably in order to keep the different tones maximally distinct perceptually." He adds that Gandour's findings for Thai support this conclusion since Thai, with 5 tones, has an even shorter duration of perturbation of the postconsonantal vowel than Yoruba which has 3 tones (p. 45). The findings for Hausa show that in some cases consonantal perturbation lasts into the C-vowel, making it more similar to English than to the other tone languages. This supports the general point being made by Hombert since Hausa has only two tones, and thus, has more 'space' for consonantal perturbations without perceptual confusions than three or five tone languages. This hypothesis predicts that languages with several tones will not have the large inventory of consonants that Hausa, with only 2 tones, allows. Furthermore, it predicts that if a language develops several tones, it will lose some of the distinctions between consonants, resulting in a more restricted, smaller inventory of consonants. An interesting result of this hypothesis is that it provides a counterexample to Hyman and Schuh's claim that "the interference of segmentals with tone processes is unidimensional; consonants affect tone, but tone does not affect consonants" (1974, p. 108). The greater the number of tones, the more restricted the consonants.

From the discussion of pitch effects at onset, transition, and during the C-vowel it was found that the pitch effects of some of the individual segments overlap at each point. For example, the pitch at onset of d and d are very similar (d: -2 hz and d: -1.7 hz). At transition the pitch effects of k, d, and t are very similar (k: +9.6 hz, d: +9.1 hz, and t: +8.8 hz). During the C-vowel the pitch effects of at least two sets of segments are very similar, g, d, and k, and 'y, c, and d (g: -.60 hz, d: -.80 hz, k: -.90 hz, and 'y: -2 hz, c: -2hz and d: -2.1 hz). Thus, pitch effects at single point in the utterance are not adequate to distinguish the segments from each other. However, if all three points which were analyzed are considered together, the pitch effects may tentatively be taken to distinguish the segments from each other. This is demonstrated below. In the first column, under *onsets*, it is noted whether or not a segment has an onset which begins at a lower pitch than the transition. Second, in the column labeled

transition, the amount of pitch raising effect is noted: L: less than 3 hz, M: 3 to 10 hz, H: more than 10 hz. In the third column, labeled *C-vowel*, the pitch effects are noted as Raising, No Effect, or Lowering. With the exception of the voiced stops, no two segments have the same pattern of effects:

Table 1.16 Patterns of Pitch Effects of Segments

<u>segment</u>	<u>onset</u>	<u>transition</u>	<u>C-vowel</u>
b	+	M	R
d	+	M	R
g	+	M	R
b	+	H	L
d	+	M	NE
t	-	M	R
k	-	H	R
k	-	M	NE
s	-	H	L
ts	-	L	L
c	-	H	NE
?	+	(none)	L
'y	+	H	NE

t has M transition where k has a H transition (in addition to differences in onset of voicing of the vowel). And the ejectives, k and ts, differ, both at transition and during the C-vowel. The laryngealized unaspirated stops b and d are also different; b has a H transition and a L vowel, where d has a M transition and a NE vowel. With the voiced stops, there are some pitch differences during the consonants themselves, since there is pitch during the voiced portion; b which has a longer period of voicing has more lowering during the consonant, while d and g each have less lowering, since they are less voiced. All these results, however, should be subjected to a statistical analysis before it can be concluded that these differences are statistically significant.

1.5.2 Comparison of the Classes of Segments

The consonant class hierarchies are presented in Figure 1.15. Pitch curves for those classes which are represented by more than one segment are given in Table 1.18. Since many of the classes are represented by only one segment, much of the data is the same as that given in Figure 1.14. With the exception of the voiceless unaspirated stops and the glottalized glide, the consonant classes can be distinguished from each other when a comparison of the pitch pattern of all three sections is made, but they are not distinguished if only one point in the utterance is used:

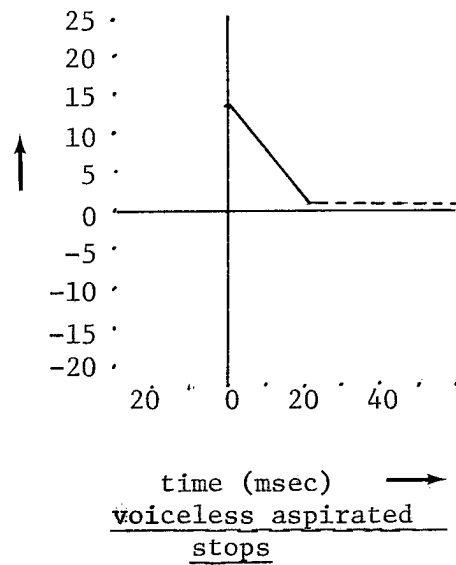
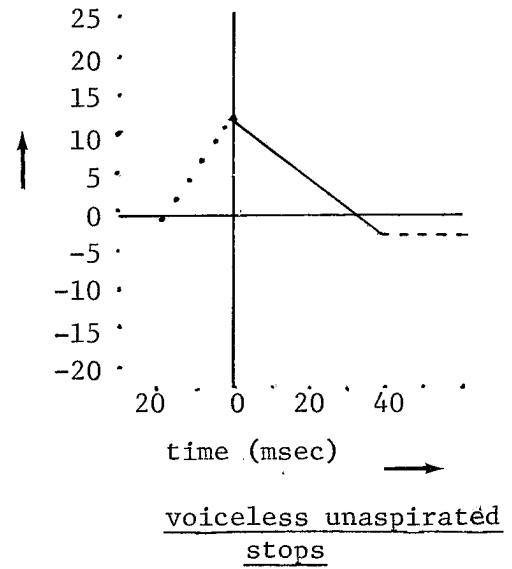
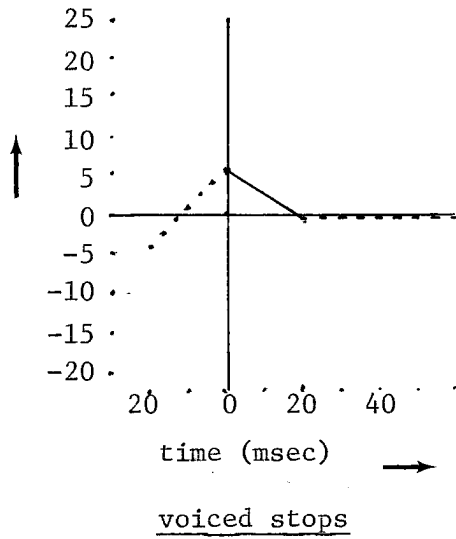


Figure 1.15: Pitch Curves for Consonant Classes.
 (See Figure 1.14 for consonant classes with one representative segment.)

Table 1.17: Consonant Class Hierarchies

<u>Onsets</u>	<u>Transitions</u>	<u>C-vowel</u>
glottal approximant	fricative	voiceless aspirated stops
voiced stops	affricate	voiced stops
voiceless unaspirated stops	voiceless aspirated stops	ejective
glottalized glide	glottalized glide	glottalized glide/affricate
voiceless aspirated stops: t, k	voiceless unaspirated stops	voiceless unaspirated stops
voiceless unaspirated stops: b, d	ejective	fricative
voiced stops: b, d, g	voiced stops	ejective fricative
glottalized glide: 'y	ejective fricative	glottal approximant
ejective stop: k		
ejective fricative: ts		
fricative: s		
affricate: c		
glottal approximant: ?		

Table 1.18: Patterns of Pitch Effects of Consonant Classes

<u>consonant class</u>	<u>onset</u>	<u>transition</u>	<u>C-vowel</u>
vl asp stp	-	H	R
vd stp	+	M	R
ejective	-	M	NE
glot glide	+	H	NE
affricate	-	H	NE
vl unasp stp	+	H	NE
fricative	-	H	L
ejective fricative	-	L	L
glot approximant	+	L	L

The voiceless unaspirated stops and the glottalized glide have the same pattern of pitch effects -- they are also very similar articulatorily. It is probable that the glottal occlusion which accompanies these segments results in the nearly identical pitch effects. The voiced stops raise pitch both at transition and during the C-vowel, contrary to what has been reported for these segments elsewhere in the literature. At transition, aspiration and affrication raise pitch more than any other segmental feature, glottal occlusion raised pitch (note the glottalized glide and the voiceless unaspirated stops). During the C-vowel voiceless stops, or partially voiceless stops (b, d, and g) raise pitch, unless there is also a glottalic component, either glottal occlusion of some sort, or ejective articulation. Non-stops, such as fricatives or approximants lower pitch during the C-vowel. The ejectives both raise pitch less than their 'plain' counterparts.

To determine which segmental features cause *significant* changes in pitch, the consonants were grouped as follows for t-tests of a priori contrasts:

1. Voiced stops (b, d, g, 22 tokens)
2. Voiceless aspirated stops (t, k, 19 tokens)
3. Voiceless unaspirated stops (b, d, 20 tokens)
4. Ejectives (k. ts, 15 tokens)
5. Affricates/Fricatives (c, s, 20 tokens)
6. Glottal Approximant (? , 9 tokens)

An analysis of variance revealed that there was a significant effect of group according to phonation type, both at transition and during the C-vowel. (At transition, $F = 17.960$, $p < .001$, during the C-vowel, $F = 11.614$, $p < .001$)

To further ascertain the effect of specific segmental features a priori contrasts (t-tests) were performed on the groups. First, groups (2) and (5) were compared with all the other groups to find whether affrication and aspiration resulted in pitch effects which were significantly different from the effects found for all other groups. It was found that the affricated and aspirated group had significantly different pitch effects both at transition ($p < .001$) and during the C-vowel ($p < .001$). At transition, the pitch measurements revealed that these segments raise pitch more than any other segment type, thus, aspiration

and affrication can be correlated with significantly higher pitch than the other segments. During the C-vowel, however, the pitch measurements obtained for these groups show that the aspirated stops still have a pitch-raising effect, while the fricatives and affricates have no effect and a slight lowering effect respectively. Next, the ejectives, group 4, were contrasted with all the voiceless obstruents, groups 2 and 5, to determine whether the glottalic component resulted in significantly different effects on pitch. The ejective articulation did result in a very significant effect at transition ($p < .001$) but the effect was only probably significant during the C-vowel ($p < .046$). In Table 1.17 it was shown that the fricatives and affricates differed in pitch effects during the C-vowel, the fricatives having a slight lowering effect, while the affricates have no effect on pitch; the voiceless aspirated stops differed from both these groups in having a raising effect. Similarly the ejectives themselves differed, the ejective stop having no effect on pitch while the ejective fricative lowered pitch. Because of these differences between the two groups and within the two groups in their effects on pitch during the C-vowel it is not surprising to find that the contrast between the two groups is only probably significant at this point. We can be certain that ejective articulation has a contrastive effect on pitch, distinguishing ejectives from the other groups, only at transition.

Next, comparison of two pairs of groups were made to see whether the voiceless unaspirated stops (group 3) were more similar to the voiced stops (group 1) or the voiceless aspirated stops (group 2). At transition, the voiceless unaspirated stops differ significantly from the voiced stops ($p < .002$) but do *not* differ significantly from the voiceless unaspirated stops ($p < .610$). During the C-vowel, however, the voiceless unaspirated stops differ significantly from *both* the voiceless aspirated stops ($p < .001$) and the voiced stops ($p < .002$). The measurements for the voiceless unaspirated stops show that, during the C-vowel, they either have no effect or a very slight lowering effect whereas the voiced stops and the voiceless aspirated stops both raise pitch. Thus, the voiceless unaspirated stops group with the voiceless aspirated stops at transition in having a pitch-raising effect, which is greater than that found for the voiced stops. During the C-vowel these segments differ in their pitch effects from both the other groups.

Finally, a comparison was made of the glottal approximant with all the other groups. This test was during the C-vowel only, since the approximant did not have transitions. It was found that the segment differed significantly ($p < .001$) from all the other groups. The measurements for the glottal approximant showed that it lowered pitch more than all other segments; it is probable that this lowering is due to creaky voice throughout the segment.

1.6 Conclusions

The data presented throughout this chapter show that Hausa consonants have predictable pitch effects, and that some of these effects are statistically significant. What role do these segmental effects on pitch play in a grammar of Hausa?

Pitch effects, such as those which were found for Hausa, have been correlated with the emergence of tones in other languages. Matisoff, in an excellent article on the emergence of lexical tone in Southeast Asian languages provides the following poetic account of the process of tonogenesis:

"In the Beginning was the Sino-Tibetan monosyllable, arrayed in its full consonantal and vocalic splendour. And the syllable was without tone and devoid of pitch. And monotony was on the face of the mora.

And Change said, "Let the consonants guarding the vowel to the left and the right contribute some of their phonetic features to the vowel in the name of selfless intersegmental love, even if the consonants thereby be themselves diminished and lose some of their own substance. For their decay or loss will be the sacrifice through which Tone will be brought into the world, that linguists in some future time may rejoice." (1973, p. 73).

Thus, Matisoff claims that lexical tone resulted from the phonologization of pitch effects which replaced other segmental features such as voicing (especially in prevocalic position) and laryngealization (in postvocalic position) as distinctive features.

Do the findings for Hausa consonants suggest how Hausa became a tone language; would the segmental effects result in future additional tones in Hausa? First, it is necessary to know whether the pitch effects can be perceived by the Hausa listener; does the literature on the perception of pitch and tone reveal whether the changes in fundamental frequency are great enough and last long enough to be used as cues to identify the segments which caused them? Second, are these cues perceptually salient for the Hausa listener? Given that he can perceive these pitch effects, it is nevertheless possible that these pitch effects are not used to distinguish the consonants from each other, but, rather, other segmental features such as voice onset time are used as the distinctive cues.

With reference to whether the effects can be perceived, the literature on the perception of synthesized vowels show that there is a "just noticeable difference" in pitch with vowels (where the F_0 is 120 hz) if the pitch change is .3 hz (Klatt, 1973) or .3 to .5 hz (Flanagan, and Saslow, 1958). Both of these findings were for fluctuations from a level synthesized vowel. If the pitch of the synthesized vowel has a descending curve (32 hz per second) a change of at least 2 hz is necessary before a difference in pitch is discriminated (Klatt, 1973). Other factors which can make it even more difficult to perceive pitch change are noise (Winkel, 1968) and the steepness of the pitch

curve. Brady, Stevens and House found that onset (or pitch perturbation) is not as salient at high glide rates; in other words, it is more difficult to perceive pitch change if the change is over a short period of time. When the pitch curve is steep subjects tended to match vowels to the end point of the contour.

Hombert (1975) conducted an experiment on perception of a synthesized vowel ([i]), varying onset pitches (70, 100, 110, 130, 140 and 190 hz) and the duration of the onset (40, 50, 100, 150 and 250 msec). The stimulus consisted of a pitch curve with an onset followed by a level vowel (120 hz). The task that the subjects were asked to perform was to listen to the stimulus, and then, by adjusting knobs controlling F_0 , match the pitch at the beginning of the stimulus vowel. He found that falling patterns are perceived more accurately than rising patterns (probably because of forward masking, see his discussion, p. 102). He also found that the longer the duration of the onset, that is the less steep the slope, the more accurately the onset was perceived (or matched). The pitch of vowels was perceived as different when the onset slope was 60 msec long, and the F_0 at onset was either 10 hz above or below the level tone of the vowel following the onsets (p. 109). It must be pointed out here that Hombert did not test for onsets which differed less than 10 hz from the pitch of the following vowel. It probably is the case that changes of less than 10 hz can be discriminated, as was shown by the other studies which were discussed above. This is crucial for the interpretation of the significance of the Hausa pitch effects, since most pitch that lasted 60 msec (that is, were still perturbing pitch during the C-vowel) deviated less than 10 hz from the pitch of the preceding vowel. Since intonational downdrift does cause lowering throughout the utterance, it is the case that these pitch effects are occurring on a downward pitch curve and thus, as Klatt found, would probably be more difficult to perceive than if they were occurring on steady state, level vowels.

But what can be perceived may not necessarily be used by a listener as a distinctive segmental feature in the grammar. As Miller so aptly put it, "one reason that nobody in recent years has been anxious to invest a great deal of effort in the precise measurement of speech sounds is that it has become increasingly obvious that the natural things to measure from an acoustic point of view are not always the important things for a listener. In fact, we now have convincing evidence that exactly the same acoustic pattern can be perceived as any one of several different phonemes, according to the company it keeps" (1958, p. 397). The 'precise measurement of speech sounds' is a necessary prerequisite to determining which patterns are used by the listener as distinctive features; the kind of study which was done in this chapter reveals which cues are available. Throughout the chapter it was also found that some of the accepted 'facts' about Hausa segments which are found in the literature are incorrect when they are subjected to close scrutiny. I agree with Miller, however, that the important question is which of the segmental effects are perceptually salient.

Although no further investigation into perceptual salience is possible for this study, Goldstein (1975) provides one framework for

further work. Goldstein investigated two segments in siSwat'i to determine whether they were discriminated on the basis of consonantal or pitch effects. The segments, /c/ and /gc/ (voiceless and voiced alveolar clicks, respectively) differed in amount of aspiration, glottal pulse differences, voice onset time (only for some of the tokens), and in having different effects on the pitch of the following vowel. Thus, "either the glottal pulse difference or the tonal depressions could be used as phonological features" distinguishing these two segments (p. 10). He had an informant record minimal pairs for the two segments, where the segments occurred before two vowels, /a/ and /u/, on high and low tone syllables. He then took one recording of the corpus and electronically spliced the consonantal portion of one segment to the vowel portion of the other segment. The informant was played both the spliced and unspliced recordings. For the high tone syllables she correctly identified all the unspliced tokens, and she identified the spliced tokens according to the vowel cues (the pitch effect cues) ignoring the contradictory consonantal cues. With low tone syllables, where the effects on tone were not as great, she consistently correctly identified 15 out of 16 (unspliced) tokens, but was inconsistent on 8 out of the 16 spliced tokens; she could not distinguish either on the basis of the pitch effects on the vowel or consonantal cues alone. She needed both consonantal and vocalic cues to distinguish the segments on low tone syllable.

Goldstein concludes that "pitch is clearly very important in distinguishing words beginning with gc from those beginning with c. Apparently, the greater the pitch difference distinguishing words of this type, the less important consonantal information (like VOT) is in making the perceptual distinction" (p. 13). It was previously pointed out, in section 5.1.1, that in tone languages the duration of pitch effect is shorter than what has been found in non-tone languages such as English. It might be argued, therefore, that tone languages are more likely to use consonantal information rather than pitch cues to identify segments, since pitch effects are restricted to avoid perceptual confusions. Many other features could influence perceptual salience, including position within the word or utterance, loudness stress and segmental context. Studies similar to Goldstein's, taking all of these variables into account, could answer the question of what role segmental pitch effects play in the synchronic grammar of Hausa. The results of such experiments would result in predictions about the possible development of additional tones, and/or the loss of segmental contrasts. The findings for the studies conducted for this chapter provide a detailed background of information for this additional research.

FOOTNOTES

1

In sections 1.4 through 5.2 of this chapter, the influence of Hausa consonants on the pitch pattern of the following vowel will be investigated. The corpus used here to determine the nature of the Hausa segments, will also be used throughout those sections. The criteria required for the corpus, listed in (a) through (e) below were chosen to eliminate as many influences on the pitch of the vowel following the consonantal segment as possible, so that all pitch perturbations on that vowel could be traced to the consonantal segment, and so that the perturbations caused by all the segments could be compared. Thus:

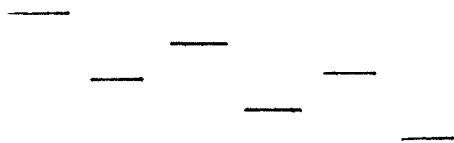
- a. The consonantal segment always occurred word initially to avoid possible pitch influences resulting from differing positions within the word.
- b. The consonantal segment was always followed by the same vowel, aa, to eliminate possible pitch influences due to vowel height, rounding etc..
- c. The segment r was chosen to follow the word initial Caa because it was found to have very minimal effects on pitch.
- d. The vowels following the word initial consonantal segments all had the same lexical tone (high).
- e. In Chapter 2, a rule will be introduced which accounts for the fact that in Hausa the second high tone in a HHL sequence is often raised. (See section 2.5) To avoid the possibility of the tone on the vowel following the consonantal segment being raised by this rule, this syllable is always followed by at least two high tone syllables.

CHAPTER 2

In this chapter I investigate the nature of Hausa tone patterns in simple sentences with downdrift. I will not be discussing sentences which include relative clauses or other dependent clauses, focus constructions, adverbial phrases or other constituents whose presence have an effect on the downdrift patterns of a sentence. These more complex sentence types will be investigated in Chapter 3. I will assume with Stockwell that "there is such a thing as a 'neutral' or 'normal' or 'colorless' intonation contour for any sentence, serving as a baseline against which all other possible contours are contrastable, and thereby meaningful" (1971, p. 25). It is these neutral sentence types, characterized by downdrift in Hausa, which will be investigated here.

Most Hausa scholars are in agreement that Hausa is a tone language with two lexical tones: high and low. Hausa also has a falling tone. In Section 2.5 I will provide evidence that the falling tone should be analyzed as a sequence of two level tones, high followed by low, as suggested by Greenberg (1941, p. 319). It has been mentioned that Hausa has downdrift. Abraham was the first to note that in Hausa "when a low tone occurs, a tone following it, whose tone is high, never quite reaches its high pitch, but stops short of it" (1941, pl 184). Hodge and Hause, in a more detailed analysis of Hausa tone, claim that "every drop from high to low is *two* (steps) and every rise from low to high, one (step)" (1941, p. 51).¹ Thus, a Hausa utterance consisting of several sequences of high-low tones is claimed to have the pattern in (1):

(1)



Even within the speech of a single speaker, pitch in Hausa is *relative*. As Pike points out, for languages with downdrift, "the absolute pitch is not pertinent as such. Rather, the pitch of one syllable in contrast to the pitches of neighboring syllables constitutes the essence of tonemic distinctions" (1967, p. vi). A high tone at the end of an utterance in Hausa may be, and quite often is, lower in pitch than a low tone at the beginning of the same utterance.

Throughout the literature on Hausa tone, downdrift is described as a downward contour that results from the unequal distances between *unlike* tones. I will show in Section 2.3, that sequences of *like* tones also manifest a downward contour. Downdrift is also traditionally described as either an *intonational phenomenon* characterizing neutral intonation, as in Kraft (1973), Hodge and Hause (1944), and Ladefoged

(1975) or as an *assimilatory process* where high tones following low tones are assimilated downward, as in Abraham (1941), Hyman (1973a), and Hyman and Schuh (1974).² I will show that downdrift in Hausa is both intonational and assimilatory.

In this chapter, I formulate an analysis of Hausa downdrift within the transformational model. Section 2.1 concerns the representation of tone in the lexicon and includes a discussion of markedness and Hausa tone. In Section 2.2 I discuss the formalization, adapted from Peters (1973), which will be used throughout the rules. I also discuss here the question of where in the grammar the feature pitch should be introduced. In Section 2.3 I discuss the specification of pitch on sequences of like tones. Then I present a rule lowering pitch after a syllable with the same value for the feature pitch. In Section 2.4 I discuss a rule which assimilates a high tone towards or to the pitch of a preceding low tone. In Section 2.5 I present two rules which assign the correct pitch distances between high tones and following low tones. In the final section of this chapter, the ordering requirements among all of the rules are investigated. Throughout my presentation phonetic evidence supporting my claims is given, along with a discussion of the implications of my findings on present claims in the literature about universals of tone.

2.1 Lexical Representation of Hausa Tone

Although there are many phonetic realizations of tone in Hausa, Hausa has only two contrasting tones, high and low. All other levels of pitch are predictable and will be derived by the rules given in the following sections. In agreement with Fromkin (1972) that "in tone languages the basic division, following Gruber and Wang, is between high and non-high tones", only one feature, [\pm high] will be used to classify Hausa tone in the lexicon.

If, as Schachter (1969) suggests, the markedness conventions should be extended to include prosodic features, it would be possible to make lexical specification of tone even less complex. Schachter claims that, universally, the unmarked value for tone is minus, thus [- high] is [μ high]. Schachter does not give supporting arguments in favor of his choice of high tone as marked beyond his claim that the unmarked value for other prosodic features such as length and stress is minus (1969, p. 25).

Fromkin (1970) provides some criteria for determining which value of a feature is unmarked. Unmarked value must be:

- a. "the less complex or normal speech sound"
- b. "the sounds or features found in most languages"
- c. "the sounds or features found with the greatest frequency in any one language"
- d. "the feature acquired earliest by children or lost last by aphasiacs"

- e. "the feature value which appears most often in neutralized environments" (1970, p. 3).

Fromkin goes on to point out that "the various criteria suggested for determining the complexity or normalcy of a feature complex may complicate rather than simplify the problem, since evidence may be found which satisfies one criterion while contradicting another".

If we apply these criteria to Hausa tone we find just such a contradiction. By criterion (a), *low tone* is probably unmarked in Hausa. While an additional articulatory gesture is always required to go to a high pitch from a low pitch, the reverse is not the case (see Section 2.4). Because of this, it can be argued that the gesture for low pitch is less complex than that required for high pitch. It is also the case that the gesture for low pitch is closer to the relaxed or normal state of the glottis than high pitch is. My data show that when an utterance begins with a lexical high tone, its phonetic realization is quite often a rising tone resulting from the adjustment of the glottis from its relaxed state towards the gesture necessary for articulating the higher pitch. This rise resembles the phonetic realization of a high tone after a low tone.³ Similarly, in final position of the utterance in Hausa, as well as many other languages, there is a strong lowering tendency, I would claim, in anticipation of the rest state, which is articulatorily similar to low pitch.

By criterion (c) however, *high tone* would be unmarked in Hausa. Hausa has a restriction against words that consist of two or more low tones only; although such words can be found in the Hausa lexicon they are, for the most part, borrowings and they are quite rare. Words that end in two low tone syllables are also infrequent (see Section 2.4). Hausa has a requirement that all disyllabic or polysyllabic words must have at least one high tone. This requirement reflects the fact that *high tone* is the "sound or feature found with greatest frequency" in Hausa (see Section 2.4).

Perhaps until more research has been done into the inter-relationships among vowel length, stress, and pitch, true generalizations about what is universally marked or unmarked with respect to these features will not be found. Even if experimental phonetic data showed that high tone in Hausa required a more complex articulatory gesture, or set of gestures, than low tone, it would be wrong to claim that an all low tone utterance was more natural or expected than an utterance containing contrastive pitches. Monotonic languages don't exist. It must be the case that pitch, stress and rhythm contrasts and patterns are necessary and natural for information processing, even if they may require more complex articulation. These contradictory requirements are related to the fact that what we as transformationalists are trying to do is characterize the competence of the ideal *speaker-hearer*. The speaker requires ease of articulation, while the hearer requires contrasts. Both are 'natural' and 'expected'. Throughout the set of rules given in the following sections we will find both these forces at work; we will find processes of dissimilation as well as assimilation, and we will find a context restriction on an assimilation rule which serves to preserve certain tonal contrasts.

2.2 Formalization

The rules to be discussed in the following sections have one main function, to assign the correct pitch to the syllables which we have seen are marked only for the classificatory feature [\pm high]. First, the feature pitch must be introduced, then correct adjustments of pitch, dependent on context, must be provided.

There are two main ways that the feature pitch could be introduced within the transformational model. First, it could be introduced with lexical redundancy rules such as those in (2) which provide a direct interpretation of the two values of the classificatory feature in numerical pitch values:

- (2) [+ High] \rightarrow [2 pitch]
 [- High] \rightarrow [5 pitch]

(Although it is confusing to use lower numbers for higher pitches and to have those rules which *lower* pitch *add* to the numerical value of the pitch, I prefer using this system since using higher numbers for higher pitches and lower numbers for lower pitches entails going into negative numbers for lower pitches in downdrift languages like Hausa, where the pitch of the utterance goes considerably lower over the length of the utterance.)

The main problem with introducing the feature for pitch this way is that it results in what Zwicky (1974) calls 'false steps', i.e., it results in allowing, at some stage in the derivation, forms which do not obey the general constraints of the language and which must, therefore, be modified further by the rules. The 'false step' in this case is that after the lexical redundancy rules have introduced the values for pitch the distance between contrasting tones is always the same, namely three pitch intervals. But in Hausa the distance between a high tone and a following low tone is *always* greater than the distance between a low tone and a following high tone. Introducing the feature pitch in the lexical redundancy rules also makes a false claim about the phonetic interpretation of the classificatory feature [\pm high]: the feature [\pm high] does *not* have an absolute phonetic interpretation, as this treatment requires, since pitch is relative in Hausa and it depends for its interpretation on the pitch of neighboring syllables.

The way to avoid these problems is by introducing the feature pitch utterance-initially by the rules given below, and adjusting other, non-initial pitch values by the rules which are given in the following sections:

- (3) Rule 1: Utterance-Initial Pitch Assignment:

[+ High] Tones

[+ H] \rightarrow [2 pitch] / # _____

Rule 2: Utterance-Initial Pitch Assignment:

[- High] Tones

[- High] → [5 pitch] / # _____

(Rules like these are used by Peters (1973, p. 150). The numbers assigned as utterance initial pitches are arbitrary, in that they cannot be translated directly into fundamental frequencies, pitch being relative from utterance to utterance (and from speaker to speaker). However, they represent real generalizations about Hausa pitch assignment. For example, utterance initial high tone is assigned a [2 pitch] value, because a rule which will be introduced in Section 2.5 assigns a higher pitch value to a high tone which is preceded by another high tone and followed by a low tone. This *raised* high tone is assigned [1 pitch].)

Throughout the rules I am adapting the formalization used by Peters to characterize downdrift in Akan. I agree with her that the adjustments of pitch required by downdrift languages "can be expressed entirely in terms of steps up or down between consecutive tones" (1973 p. 148-149). All my rules, with the exception of Rules 1 and 2, characterize the change of pitch in terms of steps up or down from the pitch of the immediately preceding syllable.

I differ from Peters in that she introduces the feature [pitch] by the following rule:

(4) [+ syl] → $\left[\begin{array}{l} + \text{ syl} \\ 0 \text{ pitch} \end{array} \right]$

Her rule requires a false step. Why introduce the feature on each syllabic segment with no value, when it must be assigned some value at a later stage in the derivation? Her rule does not represent any linguistic generalization of Hausa tone; it is just a formal device. She is still forced to introduce utterance initial pitch by rules similar to the ones in (3). And she must wipe out all other instances of [0 pitch] by her set of phonological rules. In my treatment the feature pitch is introduced throughout the rules, and is always introduced with the correct specification for the context in which the syllable occurs.

In her rules, Peters assigns pitch in a two-step process. First, on the basis of the classificatory features she assigns what she calls a "pitch increment value" either up (-) or down (+) from the pitch of the preceding syllable. Thus, to adjust the distance from high to a following low tone, she changes the pitch value from [0 pitch] to [+ 3 pitch]; in this case [+ 3 pitch] means three steps lower than the value of the pitch on the preceding, high, syllable. Her rule is:

(5) [- H] → [+ 3 pitch] / [+ High] _____

After all pitch adjustment rules have applied she computes the pitch value of all the syllables from left to right across the utterance by

the following rule:

$$(6) [q \text{ Pi}] \rightarrow [(p + q) \text{ Pi}] / [p \text{ Pi}] \text{ ______}$$

I adapt her formalization as follows. Rather than having two steps, first an increment step assigning steps up or down, and then a computational step which assigns all actual values, I assign a pitch value directly in the structural change, adjusting the output within the rule itself, without additional computation. My rule for adjusting and maintaining the correct distances between high tones and following low tones is given in (7); for the sake of this presentation it is assumed that a rule has already applied assigning a pitch value to the [+ H] syllable. A detailed discussion of this rule is presented in Section 2.5.

(7) High-Low Distance Rule

$$[- \text{H}] \rightarrow [p + 3 \text{ pitch}] / [- \text{H}] \left[\begin{array}{c} + \text{H} \\ p \text{ pitch} \end{array} \right] \text{ ______}$$

(The rule in (7) reads: In a sequence [- H] $\left[\begin{array}{c} + \text{H} \\ p \text{ pitch} \end{array} \right]$ [- H] assign the second [- H] syllable a pitch value 3 steps lower (i.e., [p + 3 pitch]), than the pitch value ([p pitch]) of the preceding [+ H] syllable. For further discussion of this rule, see Section 2.5.) Throughout the rules, pitch is introduced with respect to the pitch value of the preceding syllable. The specification of the feature pitch is introduced either as [p+n pitch], *add n* steps to the pitch value of the preceding syllable, i.e., assign a *lower* pitch value than the pitch value of the preceding syllable, or as [p-n pitch], *subtract n* steps from the pitch value of the preceding syllable, i.e., assign a *higher* pitch value than the pitch value of the preceding syllable. The only rules which introduce fixed numerical pitch specification are Rules 1 and 2, Utterance-initial Pitch Assignment. With the exception of the Like-Pitch Lowering rule, an intonational rule discussed in the next section, all of the rules are phonological rules in that the classificatory feature [\pm High] must be mentioned in the inputs of the rules, and is referred to in the structural descriptions of following rules: the feature pitch does not replace the classificatory feature high. Pitch values are assigned on the basis of the classificatory feature for tone on the preceding syllable, or, as we have seen in the rules which introduce utterance initial pitch, on the basis of the classificatory feature of tone on the syllable on which pitch is being introduced. Like-Pitch Lowering, on the other hand, assigns a pitch value to a syllable only on the basis of the pitch value of the preceding syllable, without mention of the feature [\pm High]. This is a phonetic rule of pitch assignment.

In this chapter I will formalize and discuss six rules of Hausa tone. There are other generalizations about Hausa tone which I will not attempt to include in the set of rules here. In particular, Hausa has a rule which lessens the distances between tones as the utterance progresses, at times even wiping out all contrasts by the end of a long utterance. At the beginning of an utterance, within a given

word, the distance between a high tone and a following low tone may be as great as 20 herz, while towards the end of the utterance the distance between a high and a low tone, even within the same word, may be only 2-3 herz. Also, there is a strong lowering tendency at the end of a Hausa utterance or before pause. I have not gathered enough systematic phonetic evidence to state exactly how these processes work, and cannot make explicit formal statements about either of them.

2.3 Pitch Assignment for Like-Tone Sequences

In this section I will discuss the rule which assigns pitch to sequences of like tones. Hodge and Hause claim that "a series of two or more phonemically like tones remain on the phonetic level of the first" (1944, p. 5); that is, they and other subsequent Hausa scholars claim that when a Hausa utterance contains a sequence of like tones, either a sequence of all high tones, or a sequence of all low tones, these tones will all be realized on the same phonetic pitch as the first tone in the sequence. That this is not the case can be seen in Figures 2.1 and 2.2. In both Figures 2.1 and 2.2, line (1) is the wave form, line (2) the output of the pitch meter, and line (3), the intensity channel. Lines (1) and (3) aid in the segmentation of the utterance. Figure 2.1 is of a recording of a sentence composed of high tones only:

- (8) 'yaa'yaa sun daawoo
'The children have arrived'

Each syllable is at a lower pitch than the preceding syllable, even though the sentence is composed of high tone morphemes only. The utterance begins at a pitch of 120 herz and ends at a pitch of 90 herz. Figure 2.2 is of the utterance:

- (9) Inàa dà àyabàa dà àkwàatii.
'I have a banana and a box'

This sentence is composed of an initial high tone followed by all low tone syllables. The pitch level from the first low tone syllable to the last low tone syllable descends 40 herz. Figure 2.2 demonstrates that sequences of low tones also descend in pitch. Because of data such as that shown in Figures 2.1 and 2.2, I suggest that pitch be assigned to like tone sequences by the following rule:

- (10) Rule 3: Like-Tone Pitch Assignment

$$[\alpha H] \longrightarrow [p+1 \text{ pitch}] / \left[\begin{array}{c} \alpha H \\ p \text{ pitch} \end{array} \right] \text{ ———}$$

This rule reads: The pitch of a syllable which has the same specification for the feature [H] as the preceding syllable is one step lower than the pitch of the preceding syllable. This rule is not unusual. Consecu-

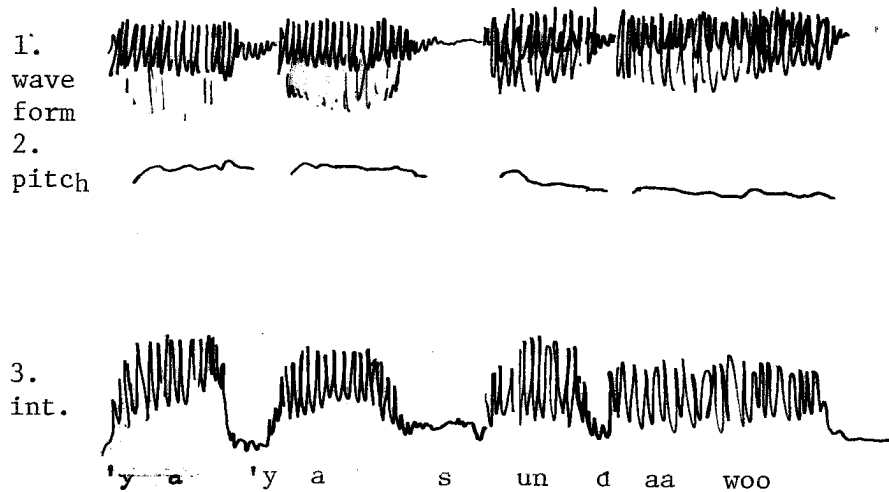


Figure 2.1: Wave form, pitch curve, and intensity for an utterance composed of high tones only.

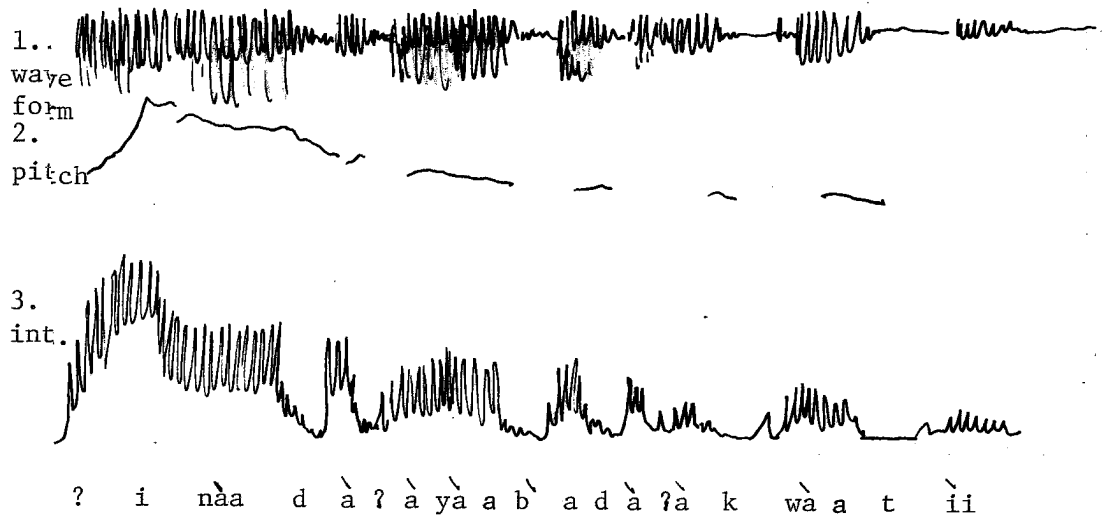


Figure 2.2: Wave form, pitch curve and intensity for an utterance composed of an initial high tone followed by nine consecutive low tones.

tive high tones are lowered in Shona, for example (Hombert, 1974).

To test this rule I taped data read by my informant and processed it as discussed in the introduction. From a corpus of 32 utterances where the structural description was met a total of ninety times, I obtained the following results:⁴

(11) Total times rule applied: 75
Total exceptions 15

All of the exceptions were cases where, in a sequence of more than two like tones, the second like tone was not lowered, but lowering began on either the third or the fourth like tone. In five of the exceptions, with sequences of like tones, the first high tone was rising towards high, the second was higher, and following high tones were lowered. In these cases, it seems that the target high was not reached by the end of the first syllable and the second syllable continued higher to reach the target. Lowering could not begin until the target high was reached. There was one utterance consisting of a sequence of five high tones, where only final lowering took place. The same kind of lowering occurs in sequences of syllables with the same specification for the feature pitch. This rule applies to the output of a rule, discussed in Section 2.4, which lowers high tones after low tones, assigning them the same pitch value as the preceding low tone. This rule is formalized in (12):

(12) Rule 4: Like-Pitch Lowering

[p pitch] → [p+1 pitch] / [p pitch] _____

This rule reads: If two syllables have the same pitch value, lower the second syllable one pitch value. (For further discussion, see Section 2.4.)

We have seen that a downward contour nearly always occurs in Hausa declarative sentences, even on sequences of like-tones only. Rule 3, Like-Tone Pitch Assignment, assigns a downward contour to *underlying* like-tones, while Rule 4, Like-Pitch Lowering, assigns a downward contour to sequential syllables which have been assigned the same pitch by a rule; thus, it assigns a downward contour to *derived* like-pitches. The smooth, gradual curve that results from Like-Tone Assignment, and Like-Pitch Lowering will be called *intonational downdrift*. It is a very natural process of lowering and probably results from a decrease in subglottal pressure as the utterance progresses. This hypothesis is tentative. I don't have experimental support for Hausa.

Since lowering occurs in the majority of languages it is a good candidate for a universal and perhaps should not be considered a rule of Hausa, but rather, an intonational universal characteristic of neutral or declarative intonation. In languages where this intonational lowering does not occur, then, such as Yoruba, it is necessary to state why it is blocked. The non-occurrence of rules like Rules 3 and 4 in Yoruba can be explained in terms of phonological space. Hausa, with

only two lexical tones, can allow sequential like tones and like pitches to take up more 'space', i.e., to descend throughout a certain range without the probability of confusion with the other lexical tone. In Yoruba, with high, mid, and low tones, if a high tone were lowered by rules like Rules 3 and 4, the lowered tone could easily be confused with a mid tone. It is probably, for perceptual reasons, that lowering rules of this sort will only occur in languages with few lexical tones. This is an example of a *hearer* constraint on a rule. Although it is easier for articulatory reasons to lower pitch as the utterance progresses, if this lowering threatens to eliminate a contrast, it is blocked. Further evidence that intonational lowering rules may be blocked to prevent the loss of a contrast is found in the way that Rule 4, Like-Pitch Lowering, interacts with Rule 5, the Low-High Distance rule, which will be discussed in detail in Section 2.5. Rule 5 lowers the pitch of a high tone when a low tone precedes it, sometimes assigning the high tone syllable the same pitch value as the preceding low tone syllable. In those instances where the resultant pitch values of the low tone and the following high tone are the same, Like-Pitch Lowering may apply, assigning the high tone syllable a pitch value one step lower than the preceding low tone. However, my data show that, in a large number of cases, Like-Pitch Lowering does not apply to the output of Rule 5, even though its structural description is met. I claim that the Like-Pitch Lowering rule is blocked because if it applied it would result in neutralization of the underlying contrast between HLH and HLL patterns, assigning both patterns a surface *high-low-lower* pitch realization. When this rule is blocked the contrast is maintained at the surface since underlying HLH patterns are assigned a *high-low-same* pitch pattern, while underlying HLL patterns are assigned a *high-low-lower* pitch realization.

A sample derivation of utterance (8), demonstrating the application of the rules presented thus far in this chapter is given below:

(13)	<u>'yaa'yaa sun daawoo</u>					
	'The children have arrived'					
	'yaa	'yaa	sun	daa	woo	<u>Lexical</u>
	[+H]	[+H]	[+H]	[+H]	[+H]	<u>Representation</u>
	[^{+H} _{2Pi}]	[+H]	[+H]	[+H]	[+H]	by Rule 1: <u>Utt. Init.</u> <u>Pi - High Tone</u>
	[^{+H} _{2Pi}]	[^{+H} _{3Pi}]	[^{+H} _{4Pi}]	[^{+H} _{5Pi}]	[^{+H} _{6Pi}]	by Rule 3: <u>Like-Tone</u> <u>Assignment</u>

2.4 Pitch Assignment for Low-High Sequences: Assimilatory Downdrift

In this section I will discuss the rule which maintains the correct pitch distances between low tones and following high tones. We have seen, in the introduction to this chapter, that although Hausa

maximizes the distance between high tones and following low tones, traditional accounts of Hausa downdrift claim that there is only one step between a low tone and a following high tone. The rule that introduces and maintains this distance both within morphemes and across morpheme boundaries is stated in (14):

(14) Rule 5: Low-High Distance Rule

$$[+H] \rightarrow [p-2 \text{ pitch}] / \left[\begin{array}{c} -H \\ p \text{ pitch} \end{array} \right] \text{ ———}$$

(This rule reads: If a high tone syllable is preceded by a low tone syllable assign it a pitch two pitch values higher than the pitch value of the immediately preceding low tone syllable.)

In Figure 2.3, I give the pitch curve of a LH word, àlloo, 'chalkboard', which has the curve predicted by Rule 5; the high tone is about 10 herz higher than the preceding low tone. The curve was obtained in the following way. The utterance was repeated five times, scattered throughout a large corpus. Pitch curves were recorded. These curves were then traced and an average curve was traced through the five samples.

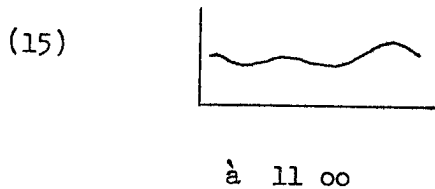


Figure 2.3: LH word in L_L frame.

Note that consonantal influence causes the curve to dip both after the release of the initial glottal stop and during the articulation of the geminate ll. Figure 2.3 shows the pitch curve of the word àlloo when it occurs in a L_L frame.

When the word àlloo occurs in isolation, the final high tone is not at the same distance from the low tone as we saw in Figure 2.3; rather it is lower as shown in Figure 2.4.

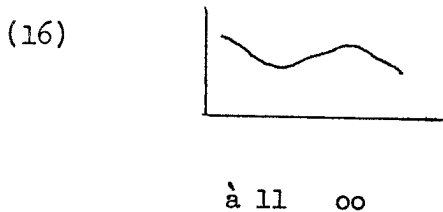


Figure 2.4: LH word in isolation.

The initial vowel is very short, immediately dipping into the lowered pitch of the geminate ll. The final vowel is at nearly the same pitch as the initial low-tone vowel. On page I discussed some generaliza-

tions about Hausa tone for which I do not have enough data to make explicit statements. In particular I said that Hausa final utterance boundaries have a very powerful lowering influence on the pitch of the last syllable of an utterance. I attribute the lowering of the final syllable of àlloo when it occurs in isolation to this utterance final lowering.

Both Figures 2.3 and 2.4 can be accounted for by this rule given in (14), the Low-High Distance rule, together with the rule discussed at the end of Section 2.2, but not formalized, which lowers pitch at the end of an utterance or before pause. However, when a *high* tone precedes the word àlloo the final high tone is lowered to the *same pitch* as, or to a lower pitch than, the preceding low tone. Since it then has the same pitch as the preceding syllable it meets the structural description of the Like-Pitch Lowering rule, and the rule may apply, lowering the final syllable to a pitch below the pitch of the preceding low tone syllable. Thus, when àlloo appeared in the frame àkwai _____ cikinsù (LH _____ HHL), it had the following curve:

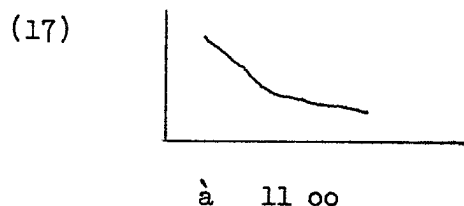


Figure 2.5: LH word in LH_HHL frame.

If it were found that such lowering occurred systematically throughout my data, the Low-High Distance rule would have to be modified. To test to see if this more complete lowering (to the pitch of the preceding low tone syllable) did occur predictably a corpus was constructed where the required sequence, HLH, occurred 47 times. I obtained the following results:

- (18) Group 1: words in isolation
 Occurred: 14 times
 Exceptions: 0
- Group 2: before L (HLHL pattern)
 Occurred: 15 times
 Exceptions: 4
- Group 3: before H (HLHH pattern)
 Occurred: 8 times
 Exceptions: 4
- Total Occurrences: 37
 Total Exceptions: 10

Because of these data, it may be concluded that lowering of pitch of a high tone syllable to the same pitch level as a preceding low tone, if that high tone syllable is preceded by the sequence HL, is:

- (19) *obligatory* with words in isolation, or utterance final or before pause,
optional but preferred if a low tone follows (HLHL pattern)
optional before a high tone (HLHH pattern).

There is a natural explanation for this distribution. First, if the high tone which is lowered by the preceding low tone is followed by a high tone, HLHH pattern, I would claim that the high tone is strengthened by the following high tone, and not as susceptible to the assimilatory strength of the preceding low tone. Second, if another low tone follows the high tone, that is, if the high tone is surrounded by low tones, it is more susceptible. Finally, if the high tone occurs utterance finally, or before pause, it is pulled down by both the preceding low tone, and the strong lowering influence of the utterance boundary or pause.

Since this kind of absolute lowering occurs predictably on LH sequences, the rule in (14) must be modified as follows:

- (20) Rule 5: Low-High Distance Rule

$$\begin{array}{l}
 \left. \begin{array}{l}
 [p-2 \text{ Pi}] \quad / \quad \left\{ \begin{array}{l} [-H] \\ \# \end{array} \right\} \left[\begin{array}{l} -H \\ p \text{ Pi} \end{array} \right] \quad \text{---} \quad (a) \\
 [p \text{ Pi}] \quad / \quad [+H] \left[\begin{array}{l} -H \\ p \text{ Pi} \end{array} \right] \quad \text{---} \quad \left\{ \begin{array}{l} \# \\ \text{pause} \end{array} \right\} \quad (b) \\
 \left\{ \begin{array}{l} [p \text{ Pi}] \\ [p-2 \text{ Pi}] \end{array} \right\} \quad / \quad [+H] \left[\begin{array}{l} -H \\ p \text{ Pi} \end{array} \right] \quad \text{---} \quad (c) \\
 \left\{ \begin{array}{l} [p \text{ Pi}] \\ [p-2 \text{ Pi}] \end{array} \right\} \quad / \quad [+H] \left[\begin{array}{l} -H \\ p \text{ Pi} \end{array} \right] \quad \text{---} \quad (d)
 \end{array} \right\}
 \end{array}$$

Conditions:

(a) and (b) are obligatory

(c) is optional but preferred / _____ L

(d) is optional

(Rule 5 reads: (a) Assign a high tone a pitch value two pitch steps higher than the pitch value of a preceding low tone when that low tone is preceded by another low tone or by an utterance boundary. (b) Assign a high tone the same pitch value as a preceding low tone if that low tone is preceded by a high tone and the context following the high tone which is being assigned pitch includes either an utterance boundary or pause. (c) Assign a high tone the same pitch value as a preceding low tone if that low tone is preceded by a high tone; if the context following the high tone being assigned pitch is a low tone this rule is optional but preferred. (d) A high tone may be assigned a

pitch value two steps higher than a preceding low tone, if that low tone is preceded by a high tone. This is the 'elsewhere' case.)⁵ The fact that Rule 5 is an assimilation rule is obscured by the fact that pitch is introduced as a context-sensitive relative feature, rather than as a direct translation of the classificatory feature. Most traditional phonologies would introduce the pitch value as the same as the high preceding the low tone, and then have an additional assimilation rule lowering high tones after low tones.

There are two main ways that Rule 5 is of interest as a linguistically significant generalization of Hausa tone. First, this kind of rule occurs in other, unrelated languages; as such it is a candidate for a linguistic universal. Meussen (1970) claims that there is a phenomenon in Bwamu, Bamileke, and Kaje which he calls *total downstep* where a high tone is assimilated to the pitch of a preceding low tone syllable, after which the conditioning low tone is lost. Second, this rule has a natural phonetic explanation, which also suggests that it is a good candidate for a tone universal. The gesture required for making a high tone is more difficult, involves more effort, than the effort that would be required to maintain a low tone over another syllable. According to Ladefoged, a change from low pitch to high pitch *always* requires a gesture of the cricothyroid muscles, but *maintaining* a low pitch quite often involves no additional articulatory gestures (Peter Ladefoged, personal communication). It is also the case that if a high tone follows a low tone in Hausa, it is usually realized as a rising tone (depending on segment type). Ohala and Ewan (1973) suggest that rising pitch requires more effort. Therefore, assimilation of high tones to preceding low tones would require less effort, and would be preferred and more natural in Hausa than articulation of a high tone after a low tone. I must stress here that I have no physiological evidence for Hausa. It is also the case that if a low tone is marked in Hausa, which would be the case by the distributional criterion cited in Section 2.1, assimilation of high tones to low tones would be assimilation to the marked feature value, and thus, natural assimilation according to the claims made by Schachter (1969, p. 342-355).

It must be noted here that although this rule is found in other unrelated languages and can be claimed, on the basis of the phonetic evidence cited above, to be a natural and expected assimilation rule, it contradicts one of the main claims about universals of tone that is found in the recent literature. Hyman and Schuh (1974) claim:

- (21) there is an "asymmetry in the tonal assimilations of lows and highs. It is often said that a high tone can raise a low tone to a high tone, but a low tone cannot lower a high tone to a low tone" (p. 96).

Schachter (1969, p. 25) makes an almost identical claim. He extends the marking conventions to include prosodic features and states that the unmarked value for the feature tone is [- tone]. (Tone is the same as my high; he uses that term to avoid possible confusion of features for vowel height with features for pitch.) He goes on to say "given

this extension of the marking conventions, the assimilation of low tones to adjacent high tones becomes interpretable as an assimilation of an unmarked to a marked feature value. Thus, such an assimilation will be specified as natural by the conventions while the hypothetical assimilation of high tones to adjacent low tones will not be so specified" (p. 25). According to both of these papers my assimilation rule is strange and unexpected.

Since this is the case, is there any other explanation for my data? It was suggested by Schachter (personal communication) that the data might be accounted for by rules similar to those that he and Fromkin suggested for Akan (1968). Perhaps the curve found in (17) Figure 2.5, where the final high tone was realized phonetically as lower than the preceding low tone, results from two rules: first, an assimilation of high tone toward the preceding low tone, and second, a raising of the low tone towards the surrounding high tones. These rules would look like:

- (22) Downstep: HLH → HLD
 Raising: HLD → HDD

If these rules were correct for Hausa they would predict the emergence of a true (phonemic) downstep tone, since the output of the Raising rule allows downstep tones where there is no conditioning low tone: in the output of the Downstep rule the downstep tone can be 'traced' to an underlying H which has been lowered by a preceding L. But in the output of the Raising rule no such explanation for the downstep tones is available.

Support for this hypothesis is found in the peculiar restriction on the environment of the Low-High Distance rule part (b), namely, that a high tone is assigned the same pitch as a preceding low tone only in the environment HL___. This is the same environment, a low surrounded by high tones, that is required for low raising in Akan. It would seem that if the Low-High Distance rule were, indeed, an assimilation rule, it should apply in the stronger assimilatory environment LL___. But if, instead of lowering, what is happening here is *raising* of a low tone between high tones, the HLH required context would be expected.

To test the hypothesis in (22), I conducted two additional experiments. First, I constructed a corpus to test whether or not the lowering of the pitch of a high tone to the pitch of a preceding low tone occurred only in HLH sequences. The following corpus was used for the experiment:

(23)	<u>LH</u>	<u>LLH</u>	<u>LHL</u>
	àlloo 'chalkboard'	àlàlaa 'bean food'	àmaana 'friendliness'
	àyuu 'bear'	àràha 'cheapness'	àlluura 'needle'
	àraa 'borrow'	ràrùmi 'grab'	àralà 'happen'

These words were selected to be as phonetically similar as possible, and to avoid possible segmental, specifically, consonantal influence on pitch. I put them in frames with the following preceding and following tones:

- (24) # _____ #
 H _____ H
 H _____ L
 L _____ H
 L _____ L

I made five recordings of each utterance (each token in each frame five times). These recordings were processed through the pitch meter and then analyzed. The results were as follows:

- (25) Lowering of a high tone to the same pitch as the pitch of a preceding low tone syllable occurred only in cases where the low tone was itself preceded by a high tone syllable (i.e., only in the context HL_____). If the preceding context contained the required high tone the rule could apply even if an all-low tone word resulted.

The (b) subpart of the rule applied to the words in the first column of (23) if a high tone preceded them, and not if a low tone preceded them. The final high tones of the LLH words in column two were never lowered. And the high tone in the LHL words in the third column was lowered if these words occurred after a high tone, but not if they followed a low tone. I included the words in the third column to test the hypothesis that the rule required a preceding high tone in order to avoid creating polysyllabic words with an all-low tone pattern. These results show that the hypothesis in (22) could be correct: one only finds the pitch pattern where the second and third syllables are on the same pitch when a high tone precedes these syllables. The rule only lowers high tones to the same pitch if the low tone syllable is surrounded by high tones. It is reasonable to surmise that the low tone could be raised by the surrounding high tones.

The second experiment I conducted tends to rule out the alternative hypothesis, however. If the low tone syllable is raised and then the following high is lowered to the same pitch the curve of a HLH sequence after the rule has applied would be different from the curve of an underlying HLL sequence. The curve of the HLH sequence should be higher, since the low is raised. To see whether the curves of these two sequences did differ, I constructed a corpus of near-minimal pairs, chosen again to avoid possible segmental influence on pitch, and to be as phonetically similar as possible:

(26)	<u>HLL</u>		<u>HLH</u>
1.	aagoòlàa	'stepchild'	agàraa 'tendon'
2.	leebùrà	'labourer'	kabàrii 'graves'
3.	oodàlè	'orderly'	aadàlii 'compassion'
4.	kaarùuwà	'prostitute'	kooraàwaa 'chasing away'

In order to be positive that the words in the second column were in fact underlying HLH, the pairs were recorded first in a context where I thought absolute lowering was least likely to occur, where the high tone was followed by a sequence of high tones: HLHHH pattern. Each token was recorded four times. Although in most cases the pitch was lowered to the same pitch as the preceding low tone, there was at least one instance for each word where the curves of the pairs differed; where the HLH words were phonetically realized as high-low-lowered high, instead of high-low-lower. This preliminary test showed that the words in the second column did have, at least in one environment, the required alternation.

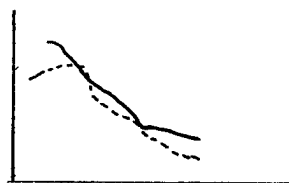
Next, I recorded each word eight times, randomly scattered throughout the corpus. The words were recorded in H___L frames. The pitch curves for all eight tokens of each type were traced, in each case using the base line of the wave form line (recorded immediately below the pitch line) as a base line, so that the pitch difference of all recordings could be compared. A line was traced through the middle of the eight pitch lines to get a normalized curve. The curves of each pair of HLH versus HLL words given in (26) were plotted against each other. The solid lines represent the HLH pattern, the dotted lines are the HLL pattern:



solid line: HLH
dotted line: HLL

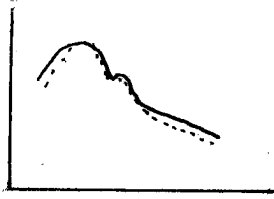
(aagoòlàa/agàraa)

Figure 2.6



(leebùrà/kabàrii)

Figure 2.7



(oodàlè/aadàlii)

Figure 2.8

solid line: HLH (karùuwà/kooràawaa)
dotted line: HLL

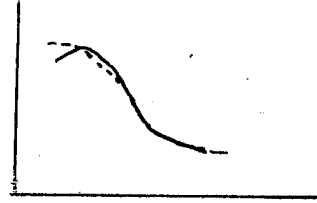
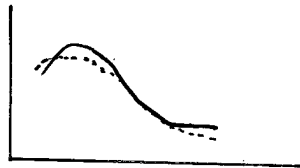


Figure 2.9

Figures 2.6-2.9 Contrasts between HLH and HLL words:
near minimal pairs.

Next, a curve was made of the normalized curves of the four HLH words and of the four HLL words. Finally, the curve representing all of the HLH words was plotted against the curve representing all of the HLL words. In Figure 2.10 this curve, averaging all occurrences of each pattern, are plotted against each other:



solid line: HLH
dotted line: HLL

Figure 2.10: Average curves of all HLH words, versus
average curves of all HLL words.

Notice that in Figure 2. the second, low, syllable is at a *lower* pitch in the HLH word than in the HLL word. And in Figures 2.8 and 2.9 the second syllable is at almost the same pitch in both the HLH and the HLL words. In Figure 2.10 the second syllable of all four HLH words is at the same pitch level as the second syllable of all four HLL words. This is evidence against the claim that the low tone syllable is raised between high tones, since in the HLL words the low tone is not surrounded by high tones and would not be likely to be raised. The main difference between the curves of these two patterns is that the final syllable of the HLL words continues downward to a lower pitch, while in the HLH words the final tone, the lowered high pitch remains at the level reached by the preceding low tone (see Figures 2.6 and 2.7). In Figure 2.8, the final syllable of the HLH word also continues downward but at a higher pitch level than the final syllable of the HLL word. In Figure 2.9, both the HLH word and the HLL word descend in pitch on the final syllable, in fact, the curves of these two words are remarkably similar. Finally, Figure 2.10, which shows the average of 32 occurrences of each pattern, shows that the final syllable of the HLL

words continues lower, by about 5 herz, than the final syllable of the HLH words. One explanation for the data is that the Like-Pitch Lowering rule does not apply obligatorily to the output of the Low-High Distance rule. I claim that the Like-Pitch Lowering rule often does not apply in just these cases in order to preserve a contrast between the HLH and the HLL patterns; the lack of lowering provides a cue that these words are underlyingly HLH. This is an example of a *hearer* constraint on the application of a rule. Although lowering is easier from an articulatory point of view, it eliminates a contrast and is, at times, blocked.

How should such a constraint be included in the grammar? There are two main ways to block Like-Pitch Lowering from applying to the output of the Low-High Distance rule. First, Like-Pitch Lowering can be reformalized so that it is optional if the syllable which is to be lowered has the classificatory feature [+H] and the preceding syllable is [-H]. But if, as I suggested in Section 2.3, Like-Pitch Lowering is an intonational universal, it would not 'cost' in Hausa, i.e., it would not increase the complexity of the grammar of Hausa. We could then posit a condition on the universal (obligatory) rule making it optional in the environment HLH: only the condition would add to the complexity of the rules:

(27) Condition on Like-Pitch Lowering

Like-Pitch Lowering is *optional* / [+H] $\left[\begin{array}{c} -H \\ p \text{ pitch} \end{array} \right] \left[\begin{array}{c} +H \\ p \text{ pitch} \end{array} \right]$

Since the curves of the HLH words did not differ from those of the HLL words in the way that the alternative hypothesis would predict, I reject it, and claim that the Low-High Distance rule given in (20) is a correct generalization about Hausa tone.

This rule is related in an interesting way to a claim made by Leben (1971) about tone in Hausa. He claims that Hausa has the following exceptionless rule:

(28) Low-Tone Raising

L L # → L H #
 [+long] [+long] (p. 202)

This rule applies to all occurrences of word final HLL sequences, where the vowel of the final syllable is long, changing the tone of the final syllable to high. Using the very powerful device of an exceptionless context-free feature-changing rule, Leben can make use of an underlying HLL pattern, which is always wiped out, to account for apparent irregularities in the tone patterns of Hausa. Making a quick check of several Hausa dictionaries I found the following counter-examples to Leben's rule:

(29)	àyàbàa 'banana'	àakaàràa 'bean cake'	agòlàa 'stepchild'
	àkwàtìì 'box'	mangwàròò 'mango'	goohòohòò 'lout'
	leebùràa 'labourer'	firamàrèè 'primary'	lahàadii 'Sunday'
	aayàlàa 'gown'	àcàkwàa 'raffia tray'	kwàdoò 'fuel bricks'

These exceptions could, of course, be marked with an exception feature in the lexicon. Evidence in favor of this treatment is found in the fact that all of the words in (29) are borrowings. So the rule in (28) could be formalized to apply only to [-foreign] words. But this treatment overlooks what I think is the correct generalization: Hausa does not have underlying HLL, LL, or LLL words except for borrowings. It is very difficult to find native Hausa words with these patterns. I tested this generalization by conducting a search in the word list in *An Introduction to Spoken Hausa* (Kraft and Abubakar, 1965). Out of approximately 680 words, only 12 had either HLL, LL or LLL patterns. Of these five were clearly borrowings, one was a reduplication of a low tone one-syllable morpheme, two more were derived from a HL plus a L morpheme or a H tone morpheme with a LL tone morpheme. Thus, out of 680 words, 4 Hausa words had one of these three patterns. (If I knew more about related Chadic languages, or other non-Chadic languages found in the area, I might be able to explain these four exceptions.) I claim that Hausa has Sequence Structure Condition:

(30) Sequence Structure Condition

1: If: [] [-H]#
 ↓
 Then: [+H] [-H]#
 (on [-foreign] words)

This constraint says that if a word ends in a low tone syllable the preceding syllable must be high.

Natural Generative Phonology disallows the use of exceptionless context-free feature-changing rules such as the one proposed by Leben in (28), since it adopts the Strong Naturalness Condition as a constraint on the theory. The Strong Naturalness Condition "requires that the underlying forms of non-alternating morphemes be identical to their phonetic representation" (Hooper, 1973, p. 21; see discussion Chapter 2). Since Leben's rule wipes out all underlying HLL patterns if the final vowel is long, there is never any alternation in the phonetic representation of the words that Leben represents as having an underlying HLL pattern. His raising rule raises all final low long syllables; these words always have a HLH pattern at the level of phonetic representation. But a more serious problem with the Low-Raising rule is that it substitutes for what should be stated as a morpheme structure

constraint, so that various inconsistencies in Hausa tone patterns can be explained using abstract underlying forms. A sequence structure constraint on possible tone sequences is and should be extremely highly valued in a grammar. The theory should be constrained to disallow the use of absolute neutralization since its use often results in just this kind of exceptionless feature-changing rule in place of the more general, more explicit, highly valued morpheme structure condition.

The Low-High Distance rule and the constraint in (30) are closely linked. If Hausa allowed underlying HLL words in the lexicon, and the set of rules presented in this chapter applied to these words, the phonetic realizations of these words would be identical to the pitch patterns of underlying HLH words in a large number of cases. There would be rampant neutralization between the words which were identical in all other ways except underlying tone patterns. I claim that the gap caused by the lack of these patterns in the Hausa lexicon is not accidental. Rather, there is a *hearer* constraint, shown in (30), which prevents these gaps from being filled.

Since this constraint is required for Hausa, my data provide a problem for Natural Generative Grammar, since in NGG the phonological rules and the morpheme structure conditions are merged into a single set of exceptionless anywhere rules. Hooper, describing the characteristics of the rules in NGG says "the phonological rules function as statements about redundancies in lexical representations. The phonological rules also have a generative function. In the course of a derivation if a structure arises which meets the SD of a phonological rule, then that phonological rule applies to that structure" (1973, p. 22). Clearly, Hausa can derive a pattern that is unacceptable as an underlying pattern in the lexicon. The pitch rules, in effect, derive the gap in the lexical patterns. I would expect to find that in other languages, as in Hausa, we would find constraints on underlying patterns in just those circumstances where the rules could result in neutralization in many cases if the gaps were filled. Because of this, I would predict that it is not possible to have a single set of rules combining both morpheme structure conditions and phonological rules.

To illustrate how the rules introduced in this section derive the correct output I provide the derivations given in (31) and (32):

(31) Gà àlloo 'Here's a chalkboard'

gà	à	llo	
[-H]	[-H]	[+H]	<u>Lexical Representation</u>
$\left[\begin{array}{c} -H \\ 5Pi \end{array} \right]$	[-H]	[+H]	by Rule 2: <u>Utt. Init. Pi.: Low Tones</u>
$\left[\begin{array}{c} -H \\ 5Pi \end{array} \right]$	$\left[\begin{array}{c} -H \\ 6Pi \end{array} \right]$	[+H]	by Rule 3: <u>Like-Tone Assignment</u>
$\left[\begin{array}{c} -H \\ 5Pi \end{array} \right]$	$\left[\begin{array}{c} -H \\ 6Pi \end{array} \right]$	$\left[\begin{array}{c} +H \\ 4Pi \end{array} \right]$	by Rule 5: <u>Low-High Distance (a)</u>

(32) aloo 'chalkboard'

à	lloo	
[-H]	[+H]	<u>Lexical Representation</u>
[-H]	[+H]	by Rule 2: <u>Utt. Init. Pi. High Tone</u>
5Pi		
[-H]	[+H]	by Rule 5: <u>Low-High Distance (b)</u>
5Pi	5Pi	
[-H]	[+H]	by Rule 4: <u>Like-Pitch Lowering</u>
5Pi	6Pi	(optional)

In (31) the derivation is given which results in a curve such as that shown in Figure 1.3, where the word appeared in a L__L frame. In (32) the derivation is given which results in a curve like that shown in Figure 1.5, where the word appeared in a LH__HHL frame.

2.5 High-Low Distance Rules

In the two preceding sections we have discussed the rules that assign and adjust the pitch of like tones and of high tones after low tones. In this section we will discuss those rules which assign and adjust the pitch distance between high tones and following low tones. Hausa has two rules which apply to this sequence of tones.

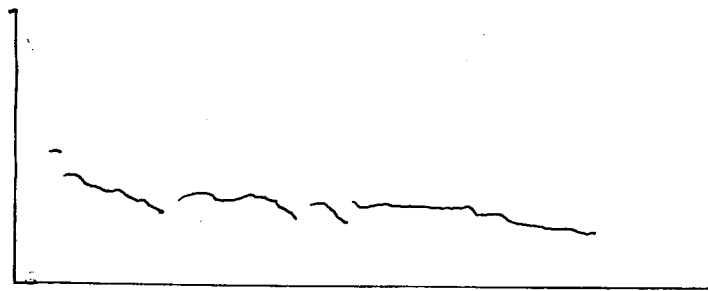
First, Hausa maximizes the distance between high tones and following low tones with a dissimilation rule which raises the last in a sequence of high tones when a low tone follows:

(33) Rule 6: High-Raising Rule

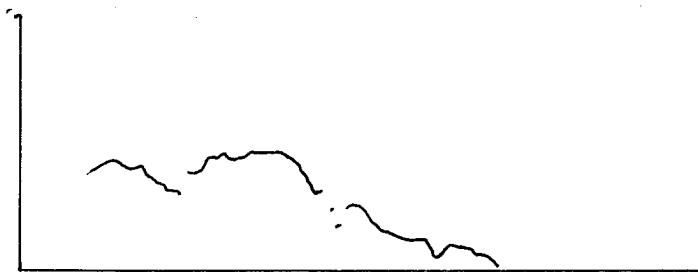
$$[+H] \longrightarrow [p-1 \text{ pitch}] / \left[\begin{array}{c} +H \\ p \text{ Pi} \end{array} \right] \text{ ——— } [-H]$$

This rule reads: Raise the last high tone in a sequence of high tones one pitch value above the pitch value of the preceding high tone if a low tone follows.

That this rule is required for Hausa can be demonstrated by the following data:



s a a b o n b i r n i i



s a a b o n g a r i i

Figure 2.11: HH word, saabon, (a) before HH word, (b) before LH word. High Raising applies in (b) but not in (a).

Figure 2.11 represents the following data:

(34) Figure 2.11 is of a minimal pair:

- a. The top graph shows the adjective saabon 'new', tone pattern HH, followed by the noun birnii 'city', also HH. High-Raising has *not* applied since its structural description was not met, and Like-Pitch Lowering has applied.
- b. The lower graph has the same high tone adjective saabon 'new', this time followed by the noun garii 'town', with a LH pattern. High-Tone Raising has applied to the second syllable of the adjective, the last high tone before the low tone, raising it 6 herz higher than the preceding high tone.

Notice that the rule applied to the word saabon only when its structural description was met. That the second syllable of the word was not raised in the top graph and was raised in the lower graph proves that the raising in the lower graph was not due to segmental influence,

vowel length or anything peculiar to the lexical item.

To test this rule I constructed a corpus where the SD of the rule was met a total of 36 times. The segmental inventory of the consonants which were to begin the syllables that I predicted would be raised was chosen so as to include each type of consonant, and the corpus was set up so that it included instances of HHL sequences both within words and across morpheme boundaries. Taped data read by my informant was processed through the pitch extraction device. I obtained the following results:

(35) Total times rule applied: 33

Total exceptions: 3

It is difficult to determine how to interpret these results. Since the rule applied in such a large number of cases it seems incorrect to decide that the rule is simply optional, or even optional but preferred. Yet I can find nothing in the data to provide an explanation of why the rule did not apply. The exceptions cannot be explained in terms of segmental influence, syntax, etc. In spite of this, I feel that the rule is obligatory. If I had a larger corpus and understood all the influences that block the rule I could predict when such exceptions would occur and make them conditions on the rule.

This rule provides some interesting support for Greenberg's hypothesis that falling tone in Hausa is a sequence of two tones, high followed by low. High-Raising applies to the initial portion of a falling tone if the preceding syllable has a high tone. This is illustrated in Figure 2.12.

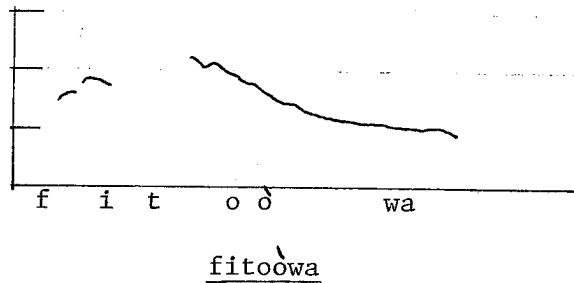


Figure 2.12: High-Falling-High word. High-Raising has applied to the second syllable.

Figure 2.12 is a pitch curve for the word *fitoòwa*, 'coming out', which has a high-falling-high tone pattern. The second syllable, begins 5 herz higher than the initial high tone. This provides phonetic evidence that Greenberg's hypothesis is correct.

The High-Raising Rule is found in other non-related languages such as Xhosa (Lanham, 1963). There is also evidence that it existed at a previous stage in Temne and Izi, and in Engenni. Meeussen and Pike claim that these languages have *upstep*, which results from the raising of a high tone before a low tone, with subsequent loss of the conditioning low tone (Meeussen 1970, Pike 1970).

Hyman and Schuh suggest that dissimilation is rarely a natural diachronic rule, because "cases of assimilation far outnumber the cases of dissimilation" and they prefer to look for alternative explanations for apparent cases of dissimilation (1974). I would argue that just as assimilation is a natural process for articulatory reasons, dissimilation is a natural process for perceptual reasons. I would explain the lack of dissimilation processes such as High-Raising in languages with many lexical tones, such as Yoruba, again in terms of phonological space. Hausa, with only two lexical tones, can allow such a rule because a high tone followed by a raised high tone cannot be misinterpreted as a mid tone followed by a high tone. Yoruba does not have a High-Raising Rule. If it did, there could be perceptual confusions between sequences of high tone followed by a raised high tone, mid tone followed by a high tone, and low tone followed by mid tone.

Next, Hausa must have a rule assigning and adjusting the distance between high tones and following low tones:

(36) Rule 7: High-Low Distance Rule

$$[-H] \rightarrow \left\{ \begin{array}{l} [p+3 \text{ pitch}] / \left\{ \begin{array}{l} [-H] \\ \# \end{array} \right\} \left[\begin{array}{l} +H \\ p \text{ Pi} \end{array} \right] \text{ ————— } \\ [p+4 \text{ pitch}] / [+H] \left[\begin{array}{l} +H \\ p \text{ Pi} \end{array} \right] \text{ ————— } \end{array} \right\} \begin{array}{l} (a) \\ (b) \end{array}$$

This rule reads: Assign a low tone syllable a pitch value 3 steps below a preceding high tone unless that high tone is preceded by another high tone, in which case assign the low tone syllable a pitch value 4 steps lower. This rule is obligatory and applies both within morphemes and across morpheme boundaries. The rule is also conjunctively ordered (according to the conventions in *The Sound Pattern of English*, Chomsky and Halle, 1968), but in this case only one subpart can apply to any given string, and extrinsic ordering is not required.

Both Rule 6, the High-Raising Rule, and Rule 7, the High-Low Distance rule conspire to maximize the distance between high tones and following low tones. If Hausa did not have a high raising rule, Like-Tone Assignment would apply to these highs bringing them closer to the low tones, thereby threatening a contrast. Similarly, part (b) of the High-Low Distance rule maintains the larger distance between the high and the following low tone after High-Raising has applied.

In (37) I provide a derivation where Rule 7 applies, and in (38) a

derivation is given where both Rule 6 and Rule 7 have applied.

(37) Naa tafi 'I went out'

naa	ta	fi	
[+H]	[-H]	[+H]	<u>Lexical Representation</u>
[^{+H} _{2P}]	[-H]	[+H]	by Rule 1: <u>Utt. Init. Pi. High Tone</u>
[^{+H} _{2P}]	[^{-H} _{5Pi}]	[+H]	by Rule 7: <u>High-Low Distance (a)</u>
[^{+H} _{2Pi}]	[^{-H} _{5Pi}]	[^{+H} _{5Pi}]	by Rule 5: <u>Low-High Distance (b)</u>

(38) saabon garii 'new town'

saa	bon	ga	rii	
[+H]	[+H]	[-H]	[+H]	<u>Lexical Representation</u>
[^{+H} _{2Pi}]	[+H]	[-H]	[+H]	by Rule 1: <u>Utt. Init. Pi. High Tone</u>
[^{+H} _{2Pi}]	[^{+H} _{1Pi}]	[-H]	[+H]	by Rule 6: <u>High-Raising</u>
[^{+H} _{2Pi}]	[^{+H} _{1Pi}]	[^{-H} _{5Pi}]	[+H]	by Rule 7: <u>High-Low Distance (b)</u>
[^{+H} _{2Pi}]	[^{+H} _{1Pi}]	[^{-H} _{5Pi}]	[^{+H} _{5Pi}]	by Rule 5: <u>Low-High Distance (b)</u>
[^{+H} _{2Pi}]	[^{+H} _{1Pi}]	[^{-H} _{5Pi}]	[^{+H} _{6Pi}]	by Rule 4: <u>Like-Pitch Lowering</u>

In (38) I derive the curve shown in Figure 2.11, lower graph.)

2.6 Rule Ordering

In this section I will discuss the ordering relationships among all of the rules given in the preceding sections. As I mentioned in Section 2.4, throughout my formalization I have attempted to formalize the rules so that extrinsic ordering is not necessary, having found that in many cases such formalization results in more explicit and more explanatory statements about processes occurring in language. I also have avoided false steps, so that the output of each rule conforms to the constraints of Hausa. In this section I will discuss problems of rule ordering which were not discussed in the preceding sections. I will also provide phonetic evidence that the application of this set of rules results in the correct phonetic output.

For convenience I list all the rules together here.

(39) Rule 1: Utterance Initial Pitch Assignment: High Tones

$$[+H] \rightarrow [2 \text{ pitch}] / \# \text{ ______}$$

Rule 2: Utterance Initial Pitch Assignment: -High Tones

$$[-H] \rightarrow [5 \text{ pitch}] / \# \text{ ______}$$

Rule 3: Like-Tone Pitch Assignment

$$[H] \rightarrow [p+1 \text{ pitch}] / \left[\begin{array}{c} H \\ pPi \end{array} \right] \text{ ______}$$

Rule 4: Like-Pitch Lowering

$$[p \text{ pitch}] \rightarrow [p+1 \text{ pitch}] / [p \text{ pitch}] \text{ ______}$$

$$\text{Condition: optional} / [+H] \left[\begin{array}{c} -H \\ pPi \end{array} \right] \left[\begin{array}{c} +H \\ pPi \end{array} \right]$$

Rule 5: Low-High Distance Rule

$$[+H] \rightarrow \left\{ \begin{array}{l} [p-2 Pi] / \left\{ \begin{array}{c} [-H] \\ \# \end{array} \right\} \left[\begin{array}{c} -H \\ pPi \end{array} \right] \text{ ______} \\ [p Pi] / [+H] \left[\begin{array}{c} -H \\ pPi \end{array} \right] \text{ ______} \left\{ \begin{array}{c} \# \\ \text{pause} \end{array} \right\} \\ \left\{ \begin{array}{c} [p Pi] \\ [p-2 Pi] \end{array} \right\} / [+H] \left[\begin{array}{c} -H \\ pPi \end{array} \right] \text{ ______} \end{array} \right. \left. \begin{array}{l} \text{(a)} \\ \text{(b)} \\ \text{(c)} \\ \text{(d)} \end{array} \right.$$

Rule 6: High-Raising Rule

$$[+H] \rightarrow [p-1 \text{ pitch}] / \left[\begin{array}{c} +H \\ pPi \end{array} \right] \text{ ______} [-H]$$

Rule 7: High-Low Distance Rule

$$[-H] \rightarrow \left\{ \begin{array}{l} [p+3 \text{ pitch}] / [-H] \left[\begin{array}{c} +H \\ pPi \end{array} \right] \text{ ______} \\ [p+4 \text{ pitch}] / [+H] \left[\begin{array}{c} +H \\ pPi \end{array} \right] \text{ ______} \end{array} \right. \left. \begin{array}{l} \text{(a)} \\ \text{(b)} \end{array} \right.$$

Rules 1 and 2 are intrinsically ordered prior to all the other rules; these rules introduce the first specifications for the feature

pitch.

Rule 3, Like-Tone Assignment, is formalized so that it avoids a false step in the grammar. This rule could have been written to assign each like tone in a sequence the same pitch value as the first like tone. Like-Pitch Lowering, Rule 4, could then apply to the output of this rule, as well as to the output of the Low-High Distance rule, lowering like-pitch syllables one pitch value. However, since like tones do not have the same pitch in Hausa this would result in a false statement about Hausa pitch patterns in the output of the rule. Since the structural change of Rule 3 does conform to the universal intonation pattern for neutral sentences, it, also should not 'cost' in the grammar of Hausa.

Like-Tone Assignment should apply to the output of the Low-High Distance rule so that after a high tone has been lowered all immediately following high tones are also lowered. That this is the case is shown in Figure 2.13 below:

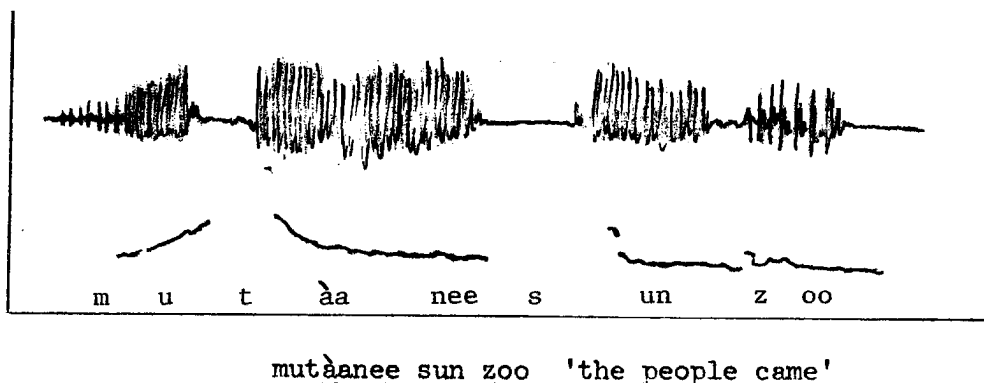


Figure 2.13: Utterance illustrating lowering of all high tones following a low tone.

The Low-High Distance Rule (b) has lowered the final high syllable of mutàanee. Like-Pitch Lowering has lowered the high tone syllable one step below the preceding low tone. Like-Tone Assignment then has assigned each following high tone a pitch value one step lower than the preceding high tone.

There is an ordering problem with respect to the Like-Tone Assignment rule and the High-Raising rule. If these rules are anywhere rules and apply whenever the structural description is met, Like-Tone Assignment can apply to the output of the High-Raising rule, lowering the raised high tone one step below the preceding high tone. A possible solution is to order High-Raising to apply after Like-Tone Assignment. Like-Tone Assignment will then assign the final high before the low a pitch value of one step lower than the preceding high tone, the same pitch assigned to all other sequence of like tones. High-Raising will then reassign this syllable a pitch one step higher than the preceding high tone. But if Like-Tone Assignment is allowed to apply in the same

environment as High-Raising, it creates a false step. In the sequence HLL in Hausa the second high tone is always raised, it is never realized as one step lower than the preceding high tone as the Like-Tone Assignment rule predicts. For this reason, simply ordering Like-Tone Assignment before High-Raising is not a satisfactory solution. Rather, the Like-Tone Assignment rule should be modified so that it does not apply to HHL sequences. This can be done in the following way:

(40) Rule 3: Like-Tone Assignment

$$[H] \longrightarrow [p+1 \text{ pitch}] / \left[\begin{array}{c} H \\ p \text{ Pi} \end{array} \right] \text{ ______ } X$$

Condition: If $X = [-H]$,
then $[H]$ must be $[-H]$

This rule and the High-Raising rule make correct explicit statements about the pitch of sequences of like tones in Hausa. Sequences of low tones are always lowered. Sequences of high tones are also lowered except before a low tone. In that environment the last high tone is raised to emphasize the contrast between the high tone and the following low tone.

Like-Tone Assignment also applies to sequences of like tones, either sequences of high tone or sequences of low tone, prior to the application of the High-Raising rule and the Low-High Distance rule. Thus, in the sequences LLLLH each low tone is lowered before the distance between the low tone and the high tone is assigned, and in the sequence HHHHL each high tone but the last is lowered before High-Raising applies. Like-Tone Assignment does not need to be extrinsically ordered with respect to any other rule. It is obligatory and applies whenever its structural description is met.

Like-Pitch lowering, Rule 4, is intrinsically ordered after Rules 1 and 2, and does not apply in the same environment as Rule 3. Like-Pitch Lowering applies optionally to the output of Rule 5, the Low-High Distance Rule (b), producing curves like that shown in Figure 2.5. It does not apply in the same environment as Rules 6 and 7. Rule 4 is an anywhere rule and applies whenever its structural description is met. This rule is obligatory except under the condition given in the rule.

Rule 5, the Low-High Distance rule, is intrinsically ordered after Rules 1 and 2. Rule 4 applies to the output of Rule 5, optionally. Rule 6, High Raising, is affected by the application of Rule 5. When the final high tone of a HLH has been assigned a pitch by the Low-High Distance rule, if the next high tone meets the structural description of the High-Raising rule it should be assigned a pitch one step above that assigned by the Low-High rule. This pattern is seen on the next page in Figure 2.14. In Figure 2.14 the initial syllable is rising towards high from utterance initial rest. The second, low syllable falls. The third, high, syllable is 2 steps above the preceding low tone. The initial syllable of Kanò has been raised by the High-Raising rule, to a pitch higher than the final high of tàfi. The initial high tone of jiyà has been lowered to the same pitch as the final low tone of Kanò. The final syllable of jiyà was not recorded by the pitch meter because it went below 70 herz. The derivation of this utterance follows Figure 2.14.

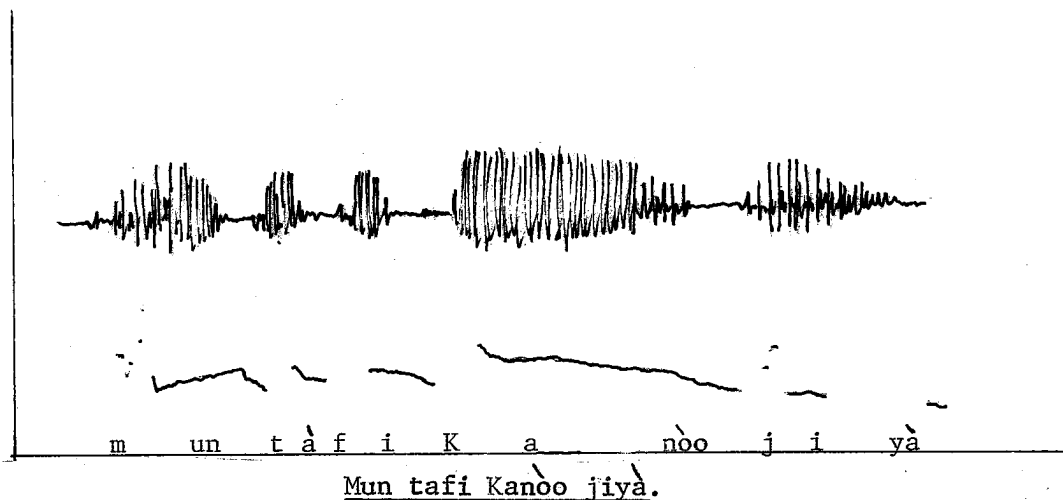


Figure 2.14: Utterance illustrating High-Raising following a lowered high tone.

(41) Mun tafi Kanoo jiya. 'We went to Kano yesterday'

mun	tà	fi	ka	nòo	ji	yà	
[+H]	[-H]	[+H]	[+H]	[-H]	[+H]	[-H]	<u>Lexical Representation</u>
[+H 2Pi]	[-H]	[+H]	[+H]	[-H]	[+H]	[-H]	Rule 1: <u>Utterance Initial Pitch: High</u>
[+H 2Pi]	[-H 5Pi]	[+H]	[+H]	[-H]	[+H]	[-H]	Rule 7: <u>High-Low Distance (a)</u>
[+H 2Pi]	[-H 5Pi]	[+H 3Pi]	[+H]	[-H]	[+H]	[-H]	Rule 5: <u>Low-High Distance (a)</u>
[+H 2Pi]	[-H 5Pi]	[+H Pi]	[+H 2Pi]	[-H]	[+H]	[-H]	Rule 6: <u>High Raising</u>
[+H 2Pi]	[-H 5Pi]	[+H 3Pi]	[+H 2Pi]	[-H 6Pi]	[+H]	[-H]	Rule 7: <u>High-Low Distance (b)</u>
[+H 2Pi]	[-H 5Pi]	[+H 3Pi]	[+H 2Pi]	[-H 6Pi]	[+H 6Pi]	[-H]	Rule 5: <u>Low-High Distance (b)</u>
[+H 2Pi]	[-H 5Pi]	[+H 3Pi]	[+H 2Pi]	[-H 6Pi]	[+H 7Pi]	[-H]	Rule 4: <u>Like-Pitch Lowering</u>
[+H 2Pi]	[-H 5Pi]	[+H 3Pi]	[+H 2Pi]	[-H 6Pi]	[+H 7Pi]	[-H 10Pi]	Rule 7: <u>High-Low Distance</u>

From Figure 2.14 we can see that the Low-High Distance (LH) rule, Rule 5, does not need to be extrinsically ordered with respect to Rule 6, the High Raising rule, or Rule 7, the High-Low Distance rule. Rule 5 does not need to be extrinsically ordered with respect to any other rule. It

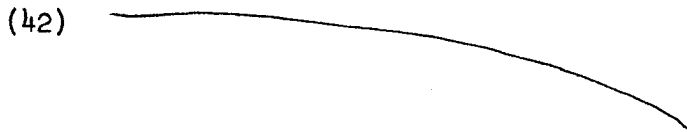
is obligatory: every H in a LH sequence must be specified for pitch either by part (a) or by part(b) of this rule.

We have already seen that Rules 6 and 7 can be unordered with respect to all other rules. Rule 6 is intrinsically ordered to apply before Rule 7.

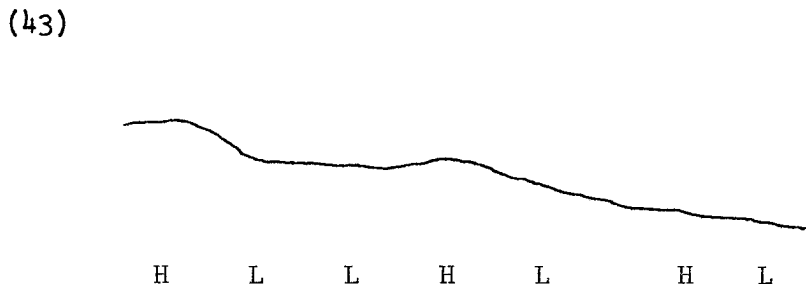
None of the rules, as they are formalized, requires extrinsic ordering to derive the correct output. The rules also state explicitly the pitch patterns found on sequences of tones in Hausa.

2.7 Conclusion

Downdrift in Hausa has been shown to be the result of the application of a set of phonological rules. There are two different patterns of downdrift in Hausa. The first, intonational downdrift is a smooth gradual curve, which results from the application of Like-Tone Assignment and Like-Pitch Lowering and looks like (42):



This type of downdrift has a natural phonetic explanation and occurs in a majority of languages in the world. It is blocked only when it threatens a contrast. The second type of downdrift, *assimilatory downdrift*, is a chunkier, less gradual curve like that shown in (43). It results from the assimilatory lowering of the Low-High Distance rule, which lowers a high tone after a low tone. Those rules which maintain the distance between a high tone and a following low tone, then lower any low tone which follows the lowered high tone pushing it lower than any preceding low tones in the utterance. Thus, the High-Low Distance rule, and the High-Raising rule maintain the distance between a high tone and a following low tone by assigning the low tone a pitch at least 3 steps lower than the preceding high tone, even if that high tone has been lowered by the Low-High Distance rule. This 'conspiracy' results in the lowering of both high tones and low tones as shown in (43):



Because of restrictions on phonological space the rules which lower pitch, Rules 2, 3, and 5, may not occur in many languages. High Raising would probably not occur also because of possible perceptual confusions. It will be interesting to find whether these rules are indeed restricted because of phonological space to languages with only few lexical tones. Such findings would better our understanding of grammars as being models of the competence of *both* the ideal *speaker* and the ideal *hearer*.

In this chapter my investigation has uncovered new facts about Hausa tone rules, and these new facts have been formalized. First, I found that sequences of like tones have a downward contour, contrary to what preceding investigators had claimed. Second, it was found that the last of a sequence of high tones occurring before a low tone is raised to maintain perceptual distance between the high tone and the following low tone. Third, further evidence was found supporting Greenberg's analysis of the falling tone as a compound tone consisting of a high tone followed by a low tone. Finally, it was found that Hausa lowers high tones towards or to the same pitch as preceding low tones. An interesting question for further investigation is whether downdrift languages such as Hausa have low tones with stronger assimilatory power than high tones, and thus have lowering rules like the Low-High Distance rule, while non-downdrift languages, such as Yoruba, allow low tone raising by the more powerful high tones.⁶

FOOTNOTES

¹Hodge and Hause, as well as many other Hausa scholars who use the term 'step' do not define it. I will use the term 'step' as well as 'one numerical pitch value' in the following way: I will assume that the native speaker categorizes pitch so that if a pitch is at a given distance from another pitch it is perceived as contrastive. This distance can be defined in terms of 'steps'. For my informant, for example, a pitch that was 10 herz lower or higher than a preceding contrastive tone was categorized as contrastive. But a distance of 5 herz was not contrastive. In this chapter a distance of two steps marks a contrast, and a distance of one step does not. When a high tone in a sequence of high tones is lowered one step it has not entered the space of a low tone. When a high tone has been lowered to within two steps of a low tone it has been assimilated to within the space of the low tone.

²Hyman and Schuh (1974) claim that downdrift may also involve the raising of a low tone between two high tones. This hypothesis is discussed in Section 2.4.

³This rising is, of course, dependent on what kind of segment occurs initially. If a liquid, nasal, or glide occurs in this position we will find just this kind of rise. If a voiceless stop occurs initially the pitch will begin high.

⁴This kind of lowering occurs regardless of what kinds of segments intervene. My corpus was constructed to include the entire distribution of Hausa segment types. Lowering occurred throughout.

⁵Hombert (1974) claims that this absolute lowering of high tones occurs only "if the intervening consonants are appropriately chosen (voiceless consonant between High and Low, voiced between Low and High)" (p. 181). That lowering of high tones is not due to segmental utterance can be shown by the following data.



The above pitch curves are of a near-minimal pair. The solid line is the pitch curve of the word talakà, HLL pattern. The dotted line is the pitch curve of the word garaakaa, HLH pattern. The Low-High Distance rule, 5(b), has applied to the final syllable, lowering it below the pitch of the preceding low tone. There is short extreme

consonantal perturbation of the pitch curve from the k at the beginning of the final syllables of both words, but the perturbation is almost identical for both words. The rule lowers the high tone syllable to the same pitch as the pitch of the underlying low tone. The rule is not blocked by the voiceless consonant as Hombert predicted it would be. Rather the lowered syllable has the same consonantal perturbation and the same pitch curve as the underlying low tone. My data to test this rule were carefully chosen to include a large inventory of segmental types to initiate the syllable which I predicted would be lowered, including at least one segment of every major segment type. In no case did I find that I could attribute the exceptions to Rule 5, (b) and (c), to segmental influence.

Hombert also claims that once the high tone has been lowered by the Low-High distance, (b) and (c), it will be realized as a level tone, whereas the preceding low tone will be realized as a fall. The levelness of the lowered high will thus provide a cue that it is underlyingly high. Although the lowered high is often realized as falling in my data, due to the application of the Like-Pitch Lowering rule, I found that in a large number of cases this lowering is blocked. Where it is blocked and final high is on the same pitch as the preceding low tone, the lack of lowering does provide a cue that the tone is not low.

⁶Yoruba has a rule raising low tone verbs to mid tone before noun objects:

L	MM	→	M	MM
tà	ata		ta	ata

'sell paper'

That this verb is underlyingly low is shown by the fact that when the noun object does not immediately follow the verb, it has a low tone:

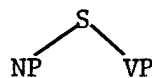
ata lí, o tà
 'pepper it is, he sold' (Courtenay, 1968, p. 77)

Chapter 3

This chapter consists of a very incomplete overview of the inter-relationship between syntax and semantics and the pitch patterns of Hausa utterances. First, I will investigate the influence that the major constituent breaks have on downdrift patterns. The syntactic points of possible influence which will be analyzed are the two main surface structure breaks in the sentence - between subject and predicate, and between verb and object. These points will be analyzed to determine whether they are characterized by any predictable pitch perturbations which could serve as perceptual cues about the surface syntactic structure of the sentence. Next, some other sentence types, differing from the 'neutral' downdrift type sentence discussed in the preceding chapters, will be presented and discussed. These 'other' sentence types include questions (yes-no and question-word questions), sentences containing the identifier particle *nee/cee* and sentences with specific lexical items which might be expected to perturb pitch, including subordinators and exclamatory particles. Especially with this latter sentence type the question will be asked whether pitch perturbations can be predictably associated with semantic and syntactic features of lexical items. Up to this point, all pitch specifications are assigned by the rules in chapter 2. In this chapter utterances which differ, syntactically or semantically, from those analyzed and accounted for by those rules will be analyzed to see to what extent the rules apply or are blocked under specific syntactic and semantic conditions. In some cases, it will be shown that additional pitch assignment rules are required in cases where, for syntactic or semantic reasons, different pitch curves from those predicted by the rules in Chapter 2 are found. At times, contrasts between tones are heightened with greater distances between tones. Pitch realizations will be found for some specific lexical items, with extreme distance between these words and surrounding syllables.

Although experimental phonetic data will be presented to illustrate the claims made throughout the chapter, the nature of the investigation differs from that found in the first two chapters. The data, which are extremely limited, only suggest directions for further research. Not enough data were collected and analyzed to provide enough tokens for statistical analyses; the data do not provide adequate definitive support for any hypotheses suggested here. All claims, then, must be considered to be tentative. For this reason, none of the suggested generalizations about the interrelationships between syntax and semantics and the pitch realization of tone are formalized. It was felt that explicit formal rules were unwarranted.

3.1.1 Subject-Predicate:



Since the subject-predicate break is the major constituent break in the sentence, it might be expected to perturb pitch the most. In a

sentence such as (1), then, a break in the downdrift pattern might be expected to occur on the first syllable of the predicate (underlined):

(1) Audù dà Alii sunàa tàfiyàa.

'Audu and Ali are leaving.'

Kraft and Kraft (1973) claim that this break in the downdrift pattern does occur in Hausa; they provide the following representation of the pitch pattern of the Hausa utterance in (1):

Table 3.1: Pitch Pattern of a Hausa Utterance showing a break in the downdrift pattern between the subject and the predicate. (Kraft and Kraft, 1973, p. 32)

5	Au	su
4	lii	fi
3	dù dà A	nàa tà
2		
1		yaa

A recording of a very similar Hausa sentence seems to support Kraft and Kraft's claim. Figure 3.1 is the wave form and the pitch curve of the following sentence:

(2) Audù dà Alii sunàa cikin tàfiyàa.

'Audu and Ali are in the midst of leaving.'

In the pitch curve in Figure 3.1, the high tone first syllable of the predicate (su) is at a higher pitch than the preceding high tone syllable. On the other hand, Figure 3.2, the wave form and pitch curve of the utterance in (3), does not support Kraft and Kraft's claim:

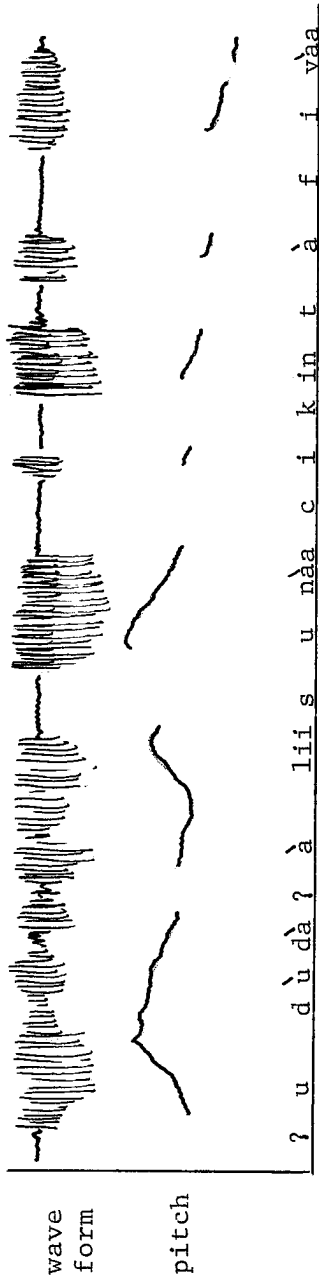
(3) Mutànee sun zoo.

'The people came.'

In Figure 3.2, the first syllable of the predicate (sun) is at a slightly *lower* pitch than the preceding high tone syllable. An explanation for this discrepancy can be found in the rules given in the preceding chapter; the structural description of the High-Raising rule is met by the utterance in Figure 3.1 and the rule applies, raising the initial syllable in the predicate:

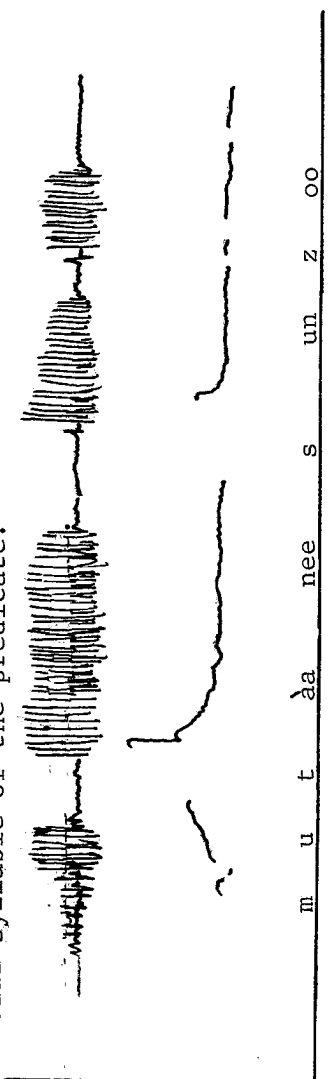
(A)	lii	su	nàa	→	(A)lii	su	nàa
(L)	H	H	L	→	H	Higher	L

In Figure 3.2 where the structural description of the High-Raising rule is not met, there is no break in the downdrift pattern between the



Audù dà Àlìi sunàa cikin tàfiyàa

Figure 3.1: Wave form and pitch curve for an utterance with raised initial syllable of the predicate.



Mutàanee sun zoo

Figure 3.2: Wave form and pitch curve for an utterance where the structural description of High-Raising is not met on the first syllable of the predicate.

subject and the predicate.

It is possible, however, that the phonological rules given in Chapter 2 are blocked or apply less often at this constituent break, and this could provide a perceptual cue about the syntactic structure of the sentence. An analysis of a corpus gathered to examine the pitch at the subject-predicate break reveals that the rules apply as follows:

(4) $\left. \begin{array}{l} \textit{Like-Tone Lowering} \\ \textit{Like-Pitch Lowering} \end{array} \right\}$ applied: 17 times
exceptions: 2

Low-High Distance Rule,
(b) and (c) applied: 11 times
exceptions: 2

(A high tone syllable, when preceded by HL__, was assigned the same pitch as the preceding low tone 11 times. A high tone syllable, when preceded by HL__, was assigned a pitch two values lower, i.e., a higher pitch, 2 times.)

High-Raising Rule applied: 6 times
exceptions: 1

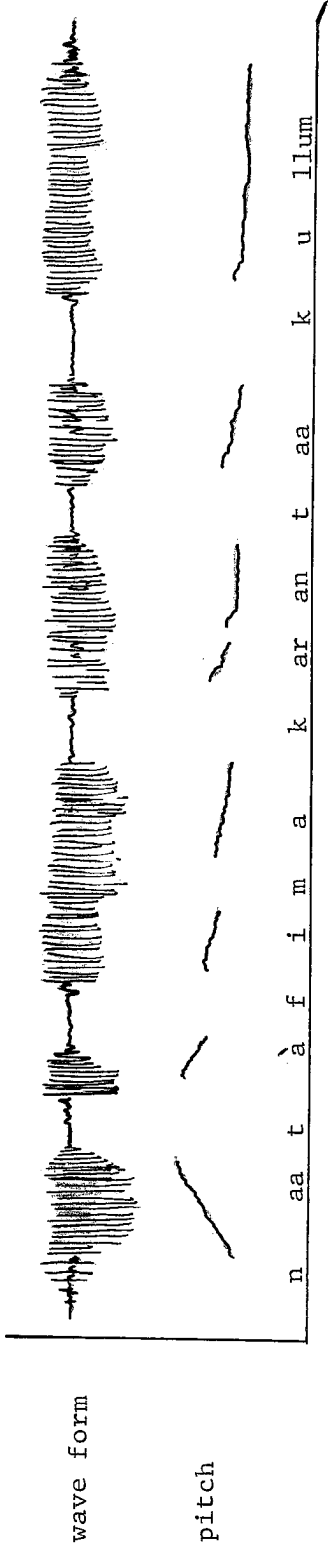
These data show that the phonological rules, including the pitch-lowering assimilation rules, apply at the subject predicate break, where the predicate begins with a high tone, with about the usual frequency.

The predicate can begin with a low tone only in negative and subjunctive sentences, and in progressive and relative progressive sentences with full noun-phrase subjects where the progressive marker *naa* is not preceded by a person marker. Some subjunctives were analyzed to determine whether, when the predicate began with a low tone, this low tone was assigned a pitch realization which differed from the pitch that would be derived by the rules in Chapter 2. First, four utterances where the low tone subjunctive marker followed a predicate final high tone were recorded and analyzed. It was found that the subjunctive low tone had a different contour than non-subjunctive low tones after high. This difference is illustrated in Figure 3.3, the pitch curves and wave forms of the utterances in (5) and (6):

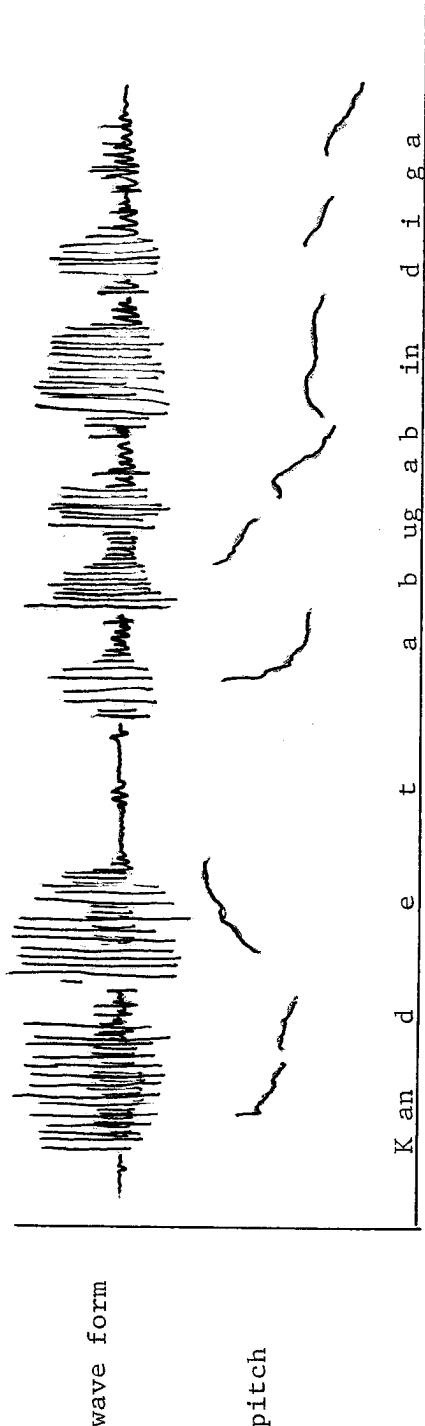
(5) *Naa tàfi makarantaa kullum.*
'I went to the market every day.'

(6) *Kande tà bugà bindigà.*
'Kande should shoot the gun.'

In Figure 3.3, line (1), the pitch curve and wave form of the sentence in (5), the initial low tone in *tàfi* begins at almost the same pitch as the end of the preceding high tone and falls. In Figure 3.3 line (2), the pitch curve and wave form of sentence (6), the subjunctive low tone *tà* begins at a pitch which is lower than the final pitch of the preceding high tone; rather than falling from high to a target low, it begins at a low pitch. This difference in contours was found in all four tokens which were recorded with predicate-initial subjunctive low tones following high tones. Another difference that was found between subjunctive



1. Naa tàfi makarantaa kullum.



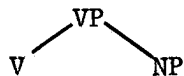
2. Kànde tà bugà bindiga.

Figure 3.3: Wave forms and pitch curves of utterances having subjunctive and non-subjunctive low tones after preceding high tone syllables.

and non-subjunctive utterances was that when the subjunctive occurred surrounded by high tones (H_H) the high tone following the subjunctive marker resisted assimilation towards the preceding low tone, and was not lowered to the same pitch as this low tone with the frequency predicted in the discussion of the Low-High Distance rule, Chapter 2. These differences can also be seen in Figure 3.3. In line (1) the high tone final syllable of *táfi* is lowered to the pitch of the preceding low tone by the Low-High Distance rule, and in line (2) the high tone initial syllable of *bindigá* is also lowered by this rule; but in line (2) the initial syllable of *bugá* which might be expected to also be lowered to the same pitch as the preceding subjunctive low tone, is realized at a pitch considerably higher than the usual distance between low tones and following high tones. This failure of the Low-High Distance rule to lower high tones following the subjunctive marker was found in all four tokens which were recorded where the HLH sequence occurred during the *initial* portion of the utterance; there were no exceptions in my data. However, if the subjunctive low tone occurred nearer the end of the utterance, utterance final lowering plus the Low-High Distance rule did result in assimilatory lowering, even after subjunctive low tones (3 tokens, no exceptions).

The data indicate that when the predicate begins with a low tone, and the subject ends in a high tone, there is a difference in the pitch realization of the predicate-initial low tone, and the distance between predicate initial low tones and following high tones differs from what was found elsewhere. All the data analyzed on low-tone initial predicates had subject final high tones so nothing can be said here about the distances between subject final low tones and predicate-initial low tones. It is impossible to determine here what purpose these different pitch realizations serve. They could serve as perceptual cues about surface syntactic structure. It is also possible that the subjunctives are assigned distinctive extreme pitch realizations because of their semantic load.

3.1.2 Verb-Object:



The other major surface structure constituent break which was analyzed to see if there were any extraordinary pitch perturbations which occurred predictably was the break between the verb and a following NP. No unusual pitch patterns were found; all the phonological rules presented in Chapter 2 applied as follows:

(7) { <i>Like Tone Lowering</i> }	applied: 7 times
{ <i>Like Pitch Lowering</i> }	exceptions: 1
<i>Low-High Distance Rule,</i>	applied: 10 times
<i>(b) and (c)</i>	exceptions: 1
<i>High-Raising Rule</i>	applied: 9 times
	exceptions: 3

The large number of exceptions to the High-Raising rule may be due to the fact that the objects of verbs in these utterances occurred near the end of the sentence - where there is less distinction between tones due to the strong lowering influence of utterance-final lowering.

In sections 3.1.1 and 3.1.2 data have been analyzed to determine whether the major constituent breaks between the subject and the predicate, and between the verb and a following object, were marked by any unusual pitch perturbations not predicted by the rules in Chapter 2, which might serve as perceptual cues to the surface syntactic structure of the utterance. It was found that when a predicate began with a high tone there were no unusual pitch patterns. A very limited amount of data on predicate-initial low tone were examined, using sentences where the predicate began with a low tone subjunctive marker. In these data it was found that a low tone subjunctive had a different pitch contour than a non-subjunctive low tone after a preceding high tone. It was also found that the phonological rules of assimilatory lowering did not apply with the usual frequency; the high tones after predicate-initial subjunctive low tones were more resistant to assimilatory lowering and were realized at a higher pitch than predicted by the rules in Chapter 2. It was argued that these differences might serve to indicate the syntactic break between subject and predicate, or they might be a way of making the subjunctive marker more distinctive because of its semantic function. With the possible exception of the subjunctive markers then, pitch perturbations were not found at these major constituent breaks; the phonologically presented in Chapter 2 applied with their usual frequency. It seems probable that pitch is not used as a perceptual cue for surface syntactic structure.

3.2.1 Interrogatives: yes-no questions

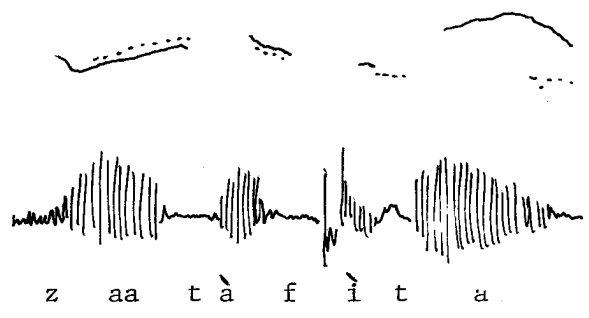
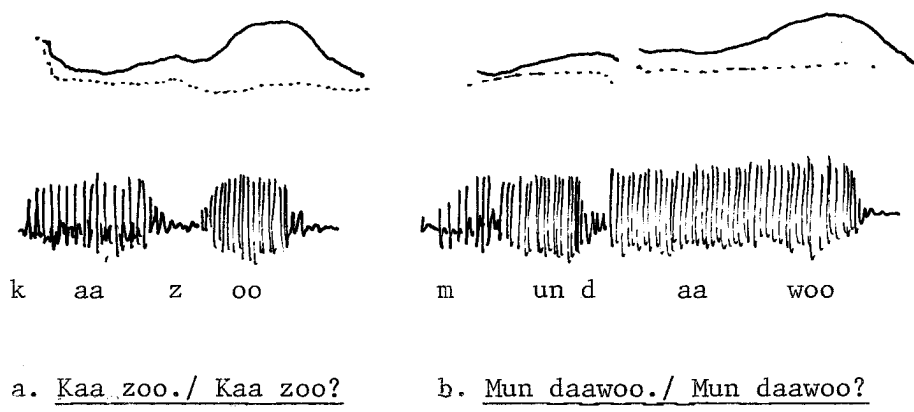
Yes-no questions in Hausa *are* marked by a difference in pitch patterns. This has been noted by various Hausaists. Hodge and Umaru (1963) do not distinguish between the intonation patterns of yes-no questions-word questions claiming that "the question intonation has an extra high pitch, with stress, on the last tone. There is a sharp drop, which falls farther if there is a low tone after the high." (p. 6) Kraft and Kraft (1973) and Cowan and Schuh (1976) provide very similar descriptions of interrogatives. They claim that there is a distinction between the pitch patterns of yes-no versus question word questions. With yes-no questions, according to Kraft and Kraft, "the last high tone in an utterance will jump to a pitch level at least one step higher than the pitch level of the preceding high tone syllable. A following low tone will drop only one step rather than all the way down to pitch level one as in the narrative contour. If a high tone syllable is final it becomes falling (as well as higher)." (1973:33) A slightly different description is provided by Hoffmann and Schachter who claim that yes-no questions "lack downdrift" and that "there is extra high tone on the last high-tone syllable and this extra high-tone is maintained on any following low-tone syllables." (1969:80).

To test these claims, some pitch curves which were recorded for Hausa statements plus their related yes-no questions are given in Figures 3.4 and 3.5. In Figure 3.4, the pitch curves and wave forms for the following pairs of sentences are presented:

- (8) a. Kaa zoo. 'You came.'
 Kaa zoo? 'Did you come?'
- b. Mun daawoo. 'We arrived.'
 Mun daawoo? 'Did we arrive?'
- c. Zaatà fìta. 'She will go out.'
 Zaatà fìta? 'Will she go out?'

The pitch curves of the questions and the statements are plotted against each other: the absolute pitch of each is given. The statement in (a) has a slight downward curve, even though it is composed of high tones only, as would be predicted by Like-Tone Lowering. The question in (a) has a raised final high tone which falls at the end of the utterance, as Kraft and Kraft predicted. In (b), another utterance composed of high tones only, the higher rising pitch of the question intonation begins during the first syllable and continues rising through the second syllable, ending in an even higher final syllable followed by a fall. That this early rising intonation is not just a case of it taking two to three syllables to reach the high tone target is shown by the fact that the statement does not show this kind of rise during the initial syllables. Sometimes, then, the higher-pitched question intonation starts earlier in the utterance than the final high tone. The pitch curves in (a) and (b) support Hodge and Umaru's claim that the entire intonation curve is at a higher pitch in questions than in statements. It is quite probable that consonants influence where the question intonation will start. The glide, w, would allow for high-pitch question intonation spreading from the end of the sentence to preceding syllables, while the fricative z, could block such spreading since it has a lowering influence on the pitch pattern during its articulation. In (c), Figure 3.4, it is shown that the final high tone syllable of the question is not lowered by either the Low-High Distance rule, or by sentence final lowering, although this combination of rules does lower the final high tone below the pitch height of the preceding low tone in the statement. This supports Hoffman and Schachter's claim that yes-no questions lack downdrift. In (c), only the first syllable of the statement is higher than the question. The final three syllables of the question are at a higher pitch than the statement. Eight pairs of statements and their related yes-no questions were analyzed; all eight had the pitch patterns just described. Some of the utterances were quite long (10-12 syllables) and the rising contour began 6-7 syllables before the final raised syllable.

Figure 3.5 shows the pitch curves and wave forms of two very similar utterances that end in a series of low tones:



c. Zaatà fìta./ Zaatà fìta?

—— question - - - - statement

Figure 3.4: Yes-No questions, final high tone. Pitch curves of questions are plotted against pitch curves of statements.

- (9) a. Kai fa, kanàa dà àyàbàa. 'You indeed have the bananas.'
 b. Kai fà, kanàa dà àyàbàa? 'What about you, do you have the bananas?'

In line (a), the statement, the last high tone, on ka, is higher than the preceding high tone because it meets the structural description of the High Rising rule:

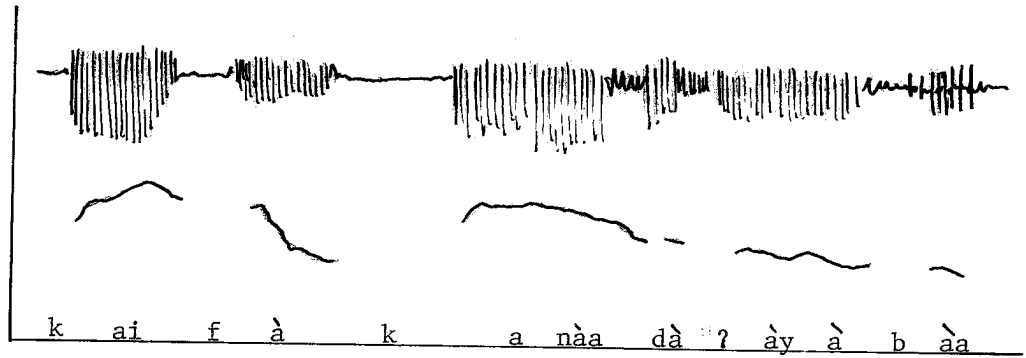
H H L → H Higher L
 fa ka nàa

In line (b), the question, however, the last high tone in the utterance, again ka, is not as high as the preceding high tone in the sentence, since it is preceded by the low tone particle fà. The low tone nàa is at almost the same pitch as ka. The last five syllables of the question are at a higher pitch than the last five syllables of the statement - in the statement all these syllables are realized at a pitch lower than 70 hz (and thus the pitch meter did not record them), in the question all the final syllables are above 70 hz. Only 3 tokens were recorded with utterance final low tones. All three tokens showed some raising of the high tones before the final low tone, and the low tones had less of a downward contour than was found for the statements.

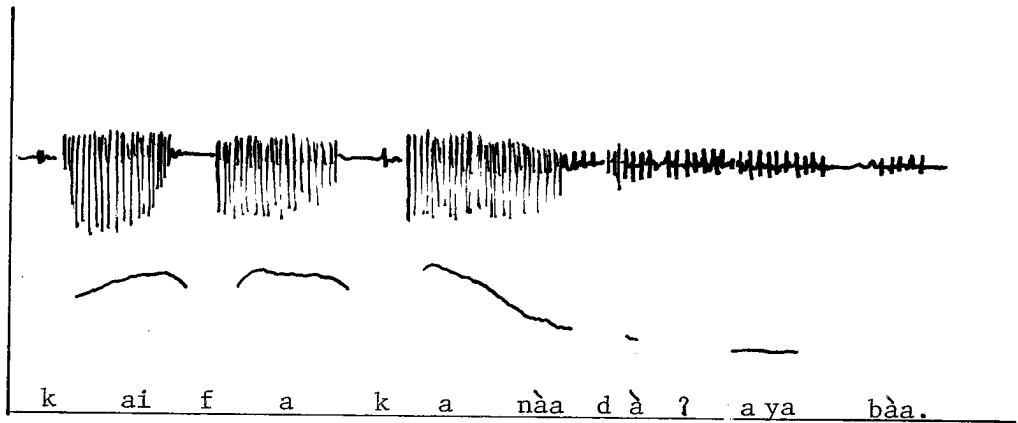
From these data it seems that yes-no questions are distinguished by having raised pitch not just on the final high tone of the utterance but throughout the utterance. It is difficult to be precise, on the basis of these limited data, as to exactly where in the utterance the higher pitched interrogative intonation begins. In some cases it does seem to occur mostly on utterance final high tones, but in other cases there is rising as early as the first syllable of the utterance. Further research would reveal what variables block or allow question intonation in the initial portions of yes-no questions. It would be of interest to investigate both consonantal influence and the influence of syntax and semantics in pairs of utterances of varying lengths.

3.2.2 Interrogatives: Question-Word Questions

Kraft and Kraft claim that question word questions differ from yes-no questions in that "1) the whole utterance is typically on a slightly higher pitch, and (2) the final tone of the utterance, if a high tone, becomes a falling tone. If the final tone of the utterance is a low tone, modification 2 does not apply". (p. 35) (Recall that Kraft and Kraft claimed that yes-no questions were characterized by changes on the last high tone of the utterance. In section 3.2.1, however, it was found that yes-no questions are characterized by a raised pitch throughout, so if this raised intonation is found for question-word questions it will not be distinctive to this question type alone.) Hoffman and Schachter, on the other hand, claim that, "questions that include an interrogative word normally have a downdrift



Kai fà, kanàa dà àyàbàa?



Kai fa, kanàa dà àyàbàa.

Figure 3.5: Yes-no question plus related statement, final low tones.

type of intonation," and the final tone of a question word question, if it is high, is "replaced by a falling tone". Some question word questions, plus their statements, were recorded to resolve this controversy.

Figure 3.6 contains the pitch curves and wave forms of the following utterances:

- (10) a. Kaa zoo. 'You came.'
 b. Kaa zoo? 'Did you come?'
 c. Yàushè ka zoo? 'When did you come?'
 d. Sun tàfi. 'They left.'
 e. Sun tàfi? 'Did they leave?'
 f. Ìnaa sukà tàfi? 'Where did they go?'

In Figure 3.6, the pitch curves of two statements, their related yes-no questions, and a related question-word question are presented. In (b) and (c) it is possible to determine that the question-word question and the yes-no question have very similar pitch curves on the words ka(a) zoo, both have raised pitch plus a final raised syllable which ends in a fall. In (d), the Low-High distance rule has lowered the final high tone below the pitch of the preceding low tone. In (c), the yes-no question of the statement in (d), this rule is blocked, and the final high tone is realized at a slightly higher pitch than the preceding high tone (on sun) and it ends in a fall. In (f), a related question-word question, a different pitch curve is found. The utterance final high tone is realized at a pitch which is *lower than the preceding high tone* (on su); it is not raised. However, like almost all interrogatives which were examined here, the final high tone is not lowered to the same pitch as the preceding low tone, as required obligatorily by the Low-High Distance rule, subpart (b). The fact that the utterance final high tone is higher in pitch than the preceding low tone demonstrates that high pitch on the final high syllable of the utterance does distinguish question-word questions from their related statements in Hausa. Notice that the utterance final high tone ends in a fall, as described by Hoffmann and Schachter.

Paul Schachter (personal communication) has suggested that there may be two separate types of pitch curves for question word questions in Hausa, the first, a *neutral* contour with downdrift, and the second a *cordial* contour which is characterized by raised pitch throughout. In the short interrogative sentences which were analyzed above, there were no instances of question-word questions with downdrift, but in some longer question word questions which were also recorded at least some portion of the utterance did have downdrift intonation, although the question-word and some portion of the clause containing the question-word always had raised interrogative intonation. Figure 3.7, the pitch curves and wave forms of two longer question-word questions, (11 a and b), illustrate this:

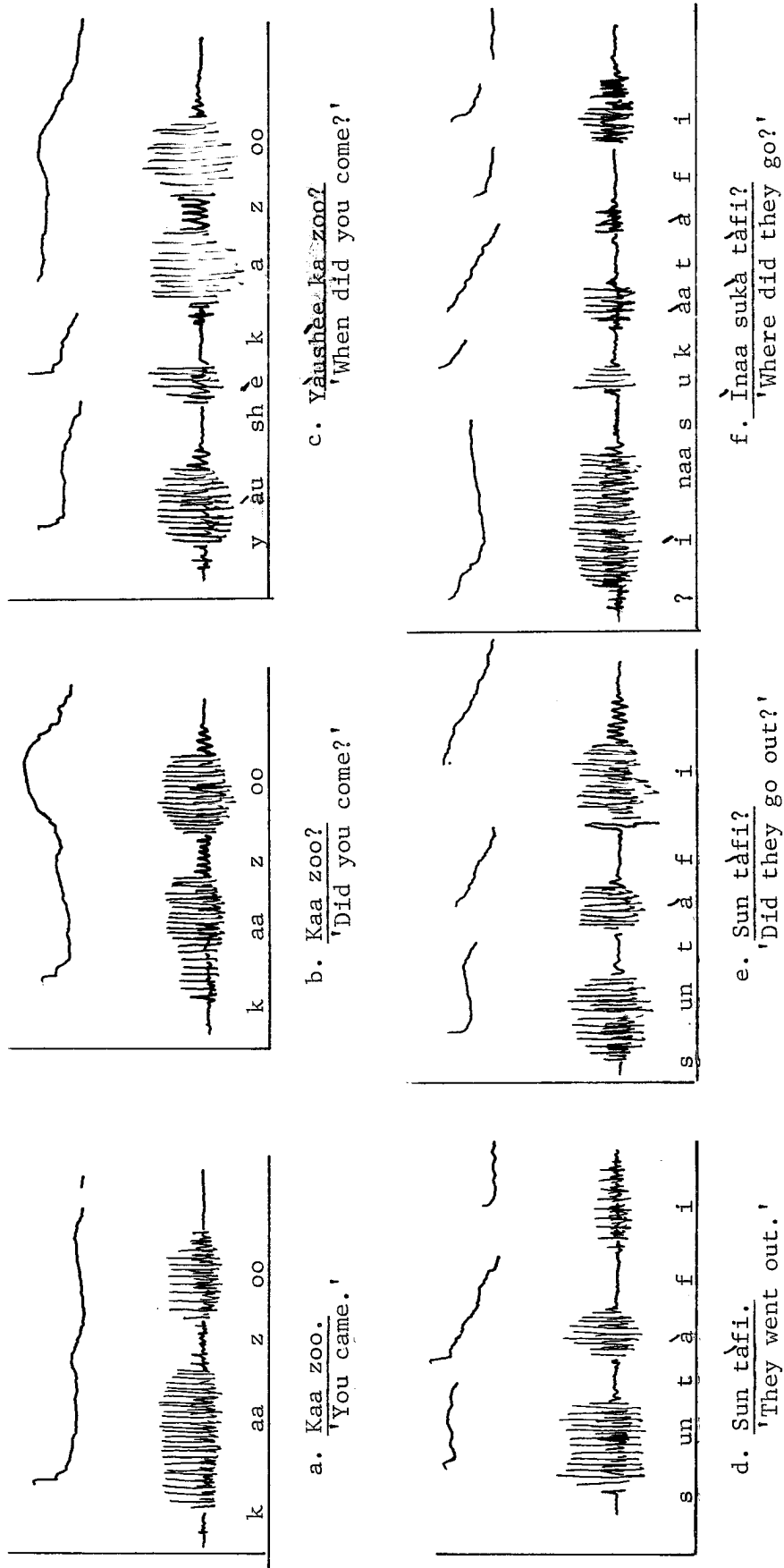


Figure 3.6: Comparisons of pitch curves of statements, yes-no questions, and question-word questions.

- (11) a. Wàa zàì kwaanaa càn cikinkù?
 'Who is going to spend the night there with you?'
- b. Wàa naa gani à gidànkà yàù dà saafee?
 'Who did I see at your house this morning?'

In line (a), the first high tone of the utterance, the first syllable of zàì, is quite high, probably due to question intonation, but the second high tone, the first syllable of the verb kwaanaa is realized at the same pitch as the preceding low tone by the Low-High Distance rule; the following two high tone syllables are also assigned this pitch by the Like-Tone Assignment rule. This portion of the utterance, kwaanaa càn, is subject to the downdrift rules. The final two high tone syllables, cin, are raised higher than what was found elsewhere in the data for high tones near the end of an utterance. Thus the question-word and some portion of the clause containing the question-word are raised, but the rest of the utterance is downdrifted. Line (b), Figure 3.7, shows another pattern for question word questions. Here, again, the question-word and the clause it occurs within is raised to a very high pitch - but the rest of the utterance had the downward contour predicted by the rules in chapter 2. The final high syllable is not lowered by utterance-final lowering, but it is also not realized at the extreme raised pitch found on final high tone syllables in yes-no questions.

These limited data show that the patterning of question-word questions is quite complex, and further research needs to be done. The data presented here suggest that question-word questions may have several intonation contours. The question word and some part of the clause containing the question-word are raised, and in several examples analyzed here, the final high tone syllable of the question-word questions was also raised. In other utterances, however, only the questioned portion of the utterance had interrogative intonation, and the rest of the utterance was downdrifted. Such factors as old versus new information, focus, and the scope of the interrogation most probably influence which kinds of pitch contours a question-word question will have. This would be a very interesting area for further research into the interaction of pitch and syntax and semantics.

3.3 Hausa sentences with the particle nee/cee

Hausa-ists, including Abraham, Hodge and Umaru, and Kraft and Kraft, have claimed that the Hausa particle nee(masculine and plural) and cee(feminine) meaning 'is, are, were', has polar tone; that is, it is assigned a tone which is "always the opposite tone of the syllable immediately preceding it". (Kraft and Kraft:97) Kraft and Kraft, for example, give the following data:

- (12) teebùr nee. 'It's a table.'
 kujèraa cèe. 'It's a chair.'

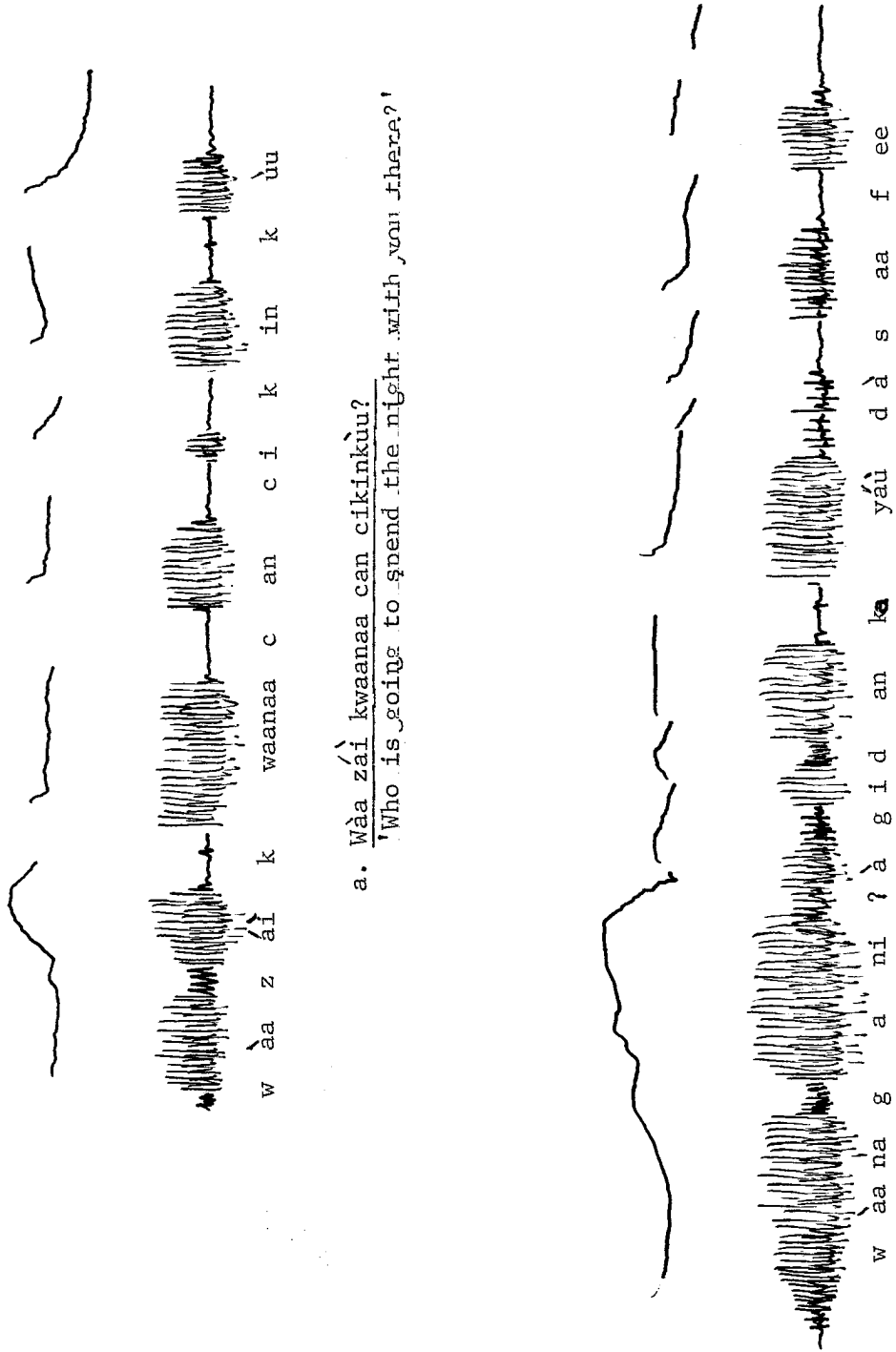


Figure 3.7: Pitch curves and wave forms of long question-word questions showing downdrift during some portion of the utterance.

The particle has high tone after the low final syllable of tebùr but low tone after the high final tone of kujèraa.

My data show that although the particle does have underlying polar tone, the particle is subject to the lowering rules described in the preceding chapter, in some cases wiping out the opposing tone if it is high following a sequence of HL. Figure 3.8 contains the pitch curves of the following sentences:

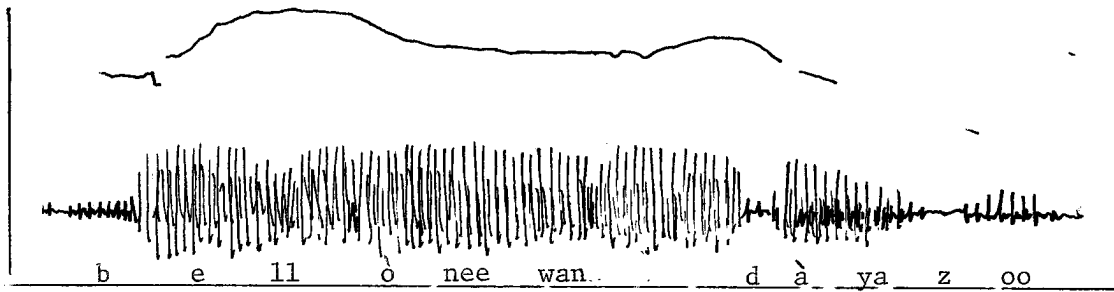
- (13) a. Bellò nee wandà ya zoo. 'Bello is the one who came.'
 b. Àyàbàa dà àkwaatii ne. 'It's bananas and a box.'
 c. Fadimatù cee. 'It's Fadimatu.'
 d. Àyàbàa cee. 'It's bananas.'

In line (a), Figure 3.8, the particle nee would be expected to have a higher pitch than the preceding low tone syllable, but the Low-High Distance rule, subpart c, has applied here, since the particle is preceded by a sequence of HL, and the particle is lower in pitch than the preceding low tone. In line (b), the particle nee is preceded by a sequence of low tones only, and does not meet the structural description of the absolute lowering subpart of the Low-High Distance rule, and thus, in spite of the powerful influence of utterance final lowering it is realized at a pitch which is slightly higher than the preceding low tone. In line (c), Figure 3.8, the particle cee is preceded by a sequence HL and is realized at a pitch lower than the preceding low tone, but in line (d), since the particle is preceded by low tones only it is realized at a higher pitch than the preceding low tone. These data show that the particle is underlyingly polar, but is subject to the assimilation rules described in Chapter 2.

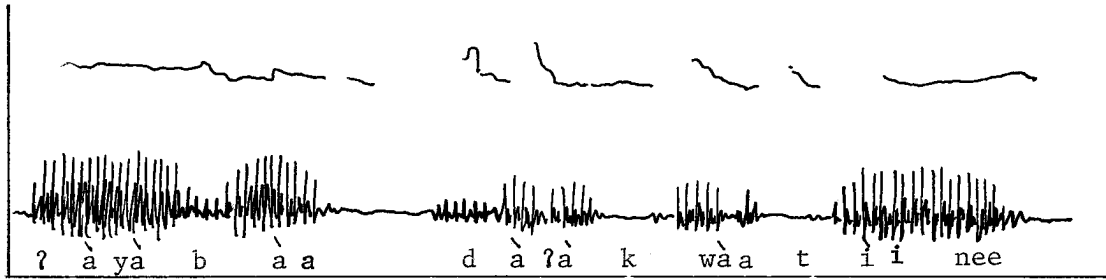
My data show that the particle is assigned a low tone after a preceding high tone, and that this low tone behaves as would be predicted by the rules in Chapter 2.

3.4 Lexical items associated with pitch perturbations

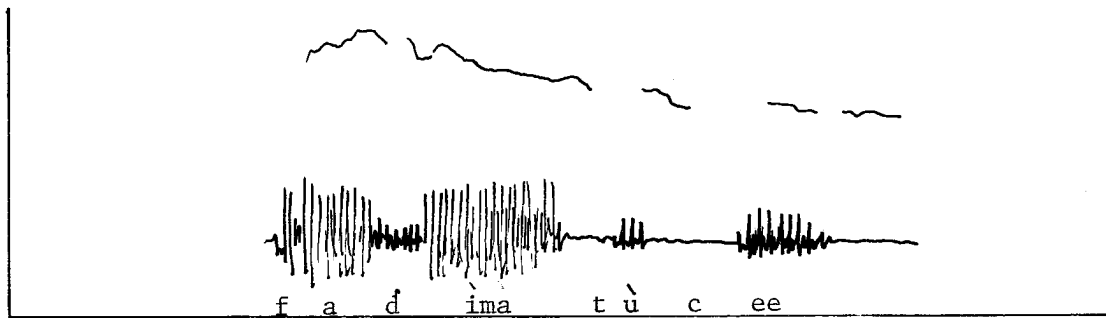
In the preceding sections it was shown that major constituent breaks do not perturb downdrift patterns, that interrogatives have pitch patterns which differ from the 'neutral' downdrift patterns of statements, and that the particle nee/cee is subject to the assimilatory and intonational lowering rules described in Chapter 2. Throughout this section lexical items will be discussed which for syntactic or semantic reasons might be expected to perturb the downdrift pattern. The first group of words which will be examined here are the modal operators sai 'only, until, and then', har 'even, until', koo 'or, even, question, if', and ammaa 'but'. These four lexical items have the characteristic that they assign a semantic reading to constituents within their scope. They interact with other factive and non-factive modal operators within the utterance, such as negation, aspect, definite and indefinite determiners, and verbs of certainty and uncertainty,



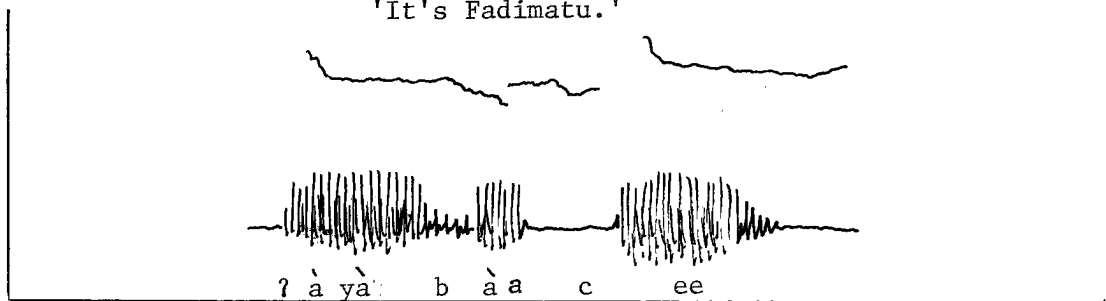
a. Bellò nee wandà ya zoo.
'It's Bello who came.'



b. Àyàbàa dà àkwàatíi ne.
'It's bananas and a box.'



c. Fadimatù cee.
'It's Fadimatu.'



d. Àyàbàa cee.
'It's bananas.'

Figure 3.8: Pitch curves and wave forms of utterances having underlying polar tone particle nee/cee.

in predictable ways. Pitch curves for utterances containing these words will be presented in section 3.4.1. The pitch patterns of two exclamations, kai and ashee, will be presented in section 3.4.2.

3.4.1 Modal Operators: sai, har and ammaa

Sai is a particle which functions as a modal: it has the meanings 'only, until, and then'. This particle is analyzed in depth in Meyers (1974a).

When sai means 'until' it occurs in sentences like (14):

- (14) Bellò bai zoo ba sai k̄arfèe biyu.
'Bello didn't come until two o'clock.'

Sai, meaning 'until' can only occur in negative sentences:

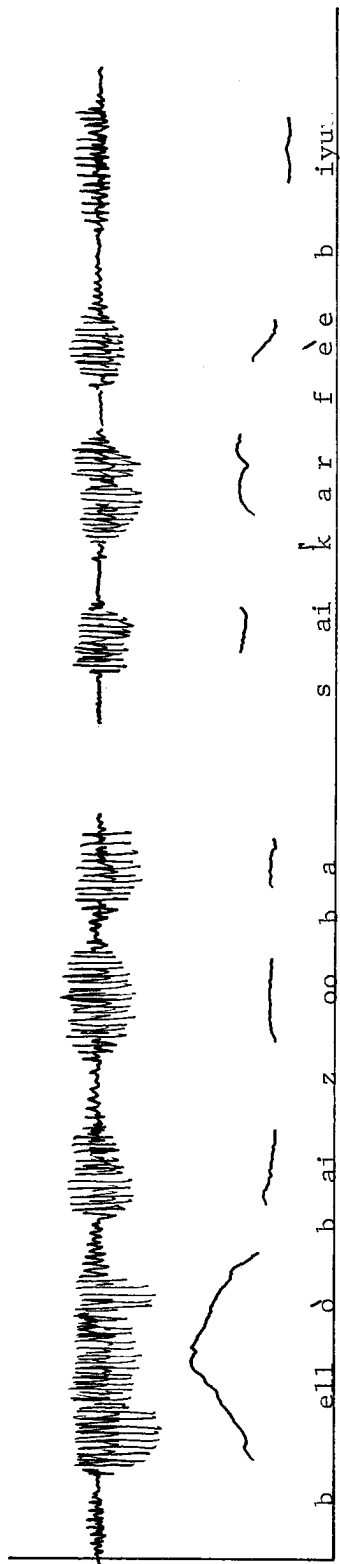
- (15) *Bellò yaa yi aikii sai k̄arfèe biyu.
'Bello worked until two o'clock.'

When sai means 'until', "it identifies a point of time (x) at which a proposition holds (Fx) and implies that for all time preceding that point of time the proposition does not hold (\sim Fy)". (p. 218) The scope of the negation of the sentence (the time during which Bello had not come in sentence (14)) extends up to the particle sai. At the time mentioned after the particle sai, Bello did come. In the pitch curve for (14), given in Figure 3.9, the portion of the utterance which begins with sai begins a new pattern of downdrift. Sai, which interrupts the scope of the negation, also interrupts the preceding downdrift pattern. Thus, the change from negative to affirmative statements about Bello's activity is signaled both by the presence of the lexical item sai, and by the beginning of a new downdrift pattern.

Another Hausa particle, har, can also mean 'until', as well as 'even'. Har differs from sai when it means 'until' in that "it refers to a set for which a given proposition holds (or does not hold) (\in F) and identifies a point of time (x) at which the given proposition also holds (or also does not hold) (\in F)". (Meyers, 1974a, p. 218) In sentence (16), then, at all relevant time the proposition Muusaa yaa yi aikii 'Musa worked' is true and the time mentioned following har does not mark a change in that proposition, it only adds the information that at k̄arfèe goomà, 'ten o'clock', Musa was working.

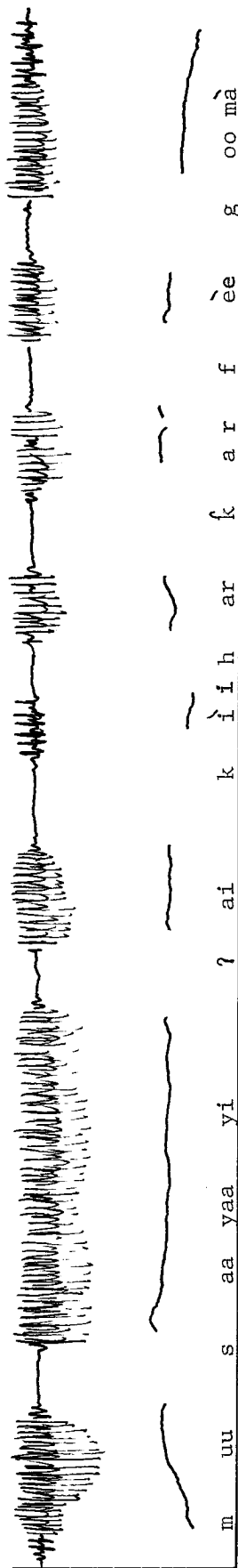
- (16) Muusaa yaa yi aikii har k̄arfèe goomà.
'Musa worked until ten o'clock.'

Since har does not introduce a new modality into the sentence, or interrupt the factive modality of the preceding perfective portion of the sentence, one might expect it not to cause the pitch perturbation - the start of a new downdrift pattern - that occurred with sai, and this is borne out by the data. Figure 3.10, the pitch curve of sentence (16)



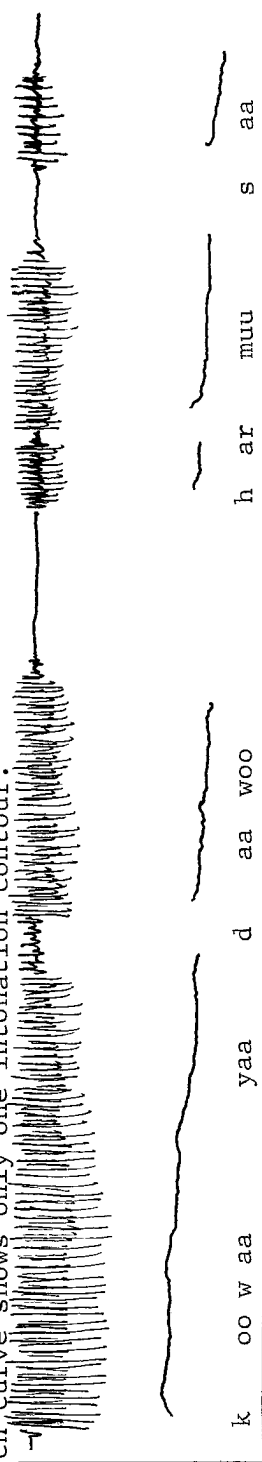
Bellò bai zoo ba sai karfee biyu.
 'Bello didn't come until two o'clock.'

Figure 3.9: Pitch curve and wave form of an utterance with the particle sai meaning 'until'. The pitch curve shows a new pattern of downdrift beginning with the particle sai.



Muusaa yaa yi aikii har karfèe goomà.
 'Musa worked until ten o'clock.'

Figure 3.10: Pitch curve and wave form of utterance with the particle har meaning 'until'. The pitch curve shows only one intonation contour.



Koowaa yaa daawoo har Muusaa.
 'Everyone came back even Musa!'

Figure 3.11: Pitch curve and wave form of utterance with the particle har meaning 'even'. The pitch curve shows only one intonation contour.

illustrates this. Although there are clearly two phrases in Figure 3.12 - there is only one intonation contour. (The initial syllable of the word karfèe in Figure 3.10 is at a higher pitch than har; this is because it has been raised by the High-Raising rule.)

Har can also mean 'even' in sentences like (17):

- (17) Koowaa ya daawoo, har̩ .Muusaa.
'Everyone came back, even Musa.'

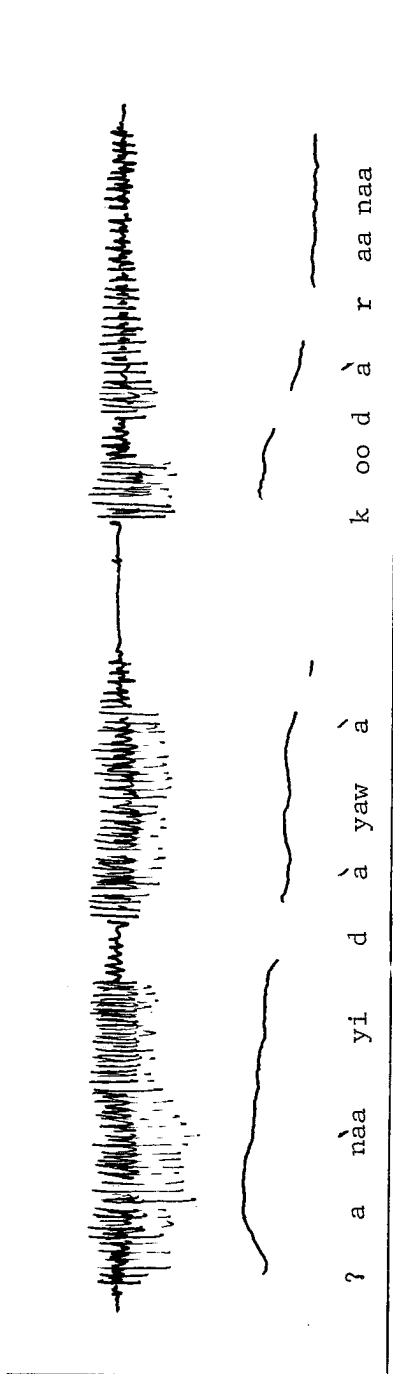
When har means 'even' it defines a set and adds the information that there is an additional member of that set; so in (17) the set is defined by koowa ya daawo 'everyone came back' and Musa is defined as an additional member of the set. (Sentence (17) does not contain a presupposition or implication that the speaker is surprised that Musa is a member of the set; if such a presupposition is required, the word ko, which also means 'even' is used.) The pitch curve for sentence (17) is given in Figure 3.11. Again, in this use of har, where the particle does not introduce a new semantic reading only one downdrift intonation contour is present in the utterance.

In a previous analysis of the Hausa particle koo (Meyers, 1974b) it was determined that the particle functions as an uncertainty modality in Hausa. That is, the particle has the property that those constituents which fall within its scope "are assigned a reading, namely, that the speaker does not assert, and is uncertain of, the truth of just those constituents within the sentence". (p. 262) When the non-factive uncertainty modal koo occurs within the scope of a more powerful factive modality it carries a presupposition on the part of the speaker that the hearer would share his surprise that the assertion is true of the constituents within its scope.¹ Thus, in sentence (18), the speaker is expressing his surprise that koo dà raanaa 'even in the daytime' the preceding assertion, anàa yi dà yawa 'they do a lot', is true:

- (18) Anàa yi dà yawà koo dà raanaa.
'They do a lot even in the daytime.'

In Figure 3.12, the portion of the utterance that starts with koo interrupts the preceding pattern of downdrift, initiating a new pattern. The interruption of the assertion scope by the uncertainty modality koo is marked by a change in the pitch pattern. When har was used to mean 'even' in sentence (17), figure 3.11, there was only a single downdrift pattern since har does not block the assertion scope of the preceding portion of the utterance. Four recordings were analyzed of sai meaning 'until', har meaning 'until', har meaning 'even' and koo meaning 'even'. All had the contours described here. The pitch perturbations which were found with sai and koo are linked to semantic characteristics of these specific lexical items.

Another lexical item which might be expected to have an effect on the downdrift pattern of a sentence is the coordinating conjunction ammaa 'but'. It marks the beginning of a phrase which is in some way contradictory or unexpected in contrast to what preceded that phrase in



Anàa yi dà yawà koo dà raanaa.
 'They do a lot, even in the daytime.'

Figure 3.12: Pitch curve and wave form for an utterance with the particle koo meaning 'even'. The pitch curve shows a new pattern of downdrift beginning with koo.

the utterance. As such, it resembles the modalities which have been discussed so far in this section, and might be expected to interrupt the downdrift pattern. While sai, har and koo all have lexical high tone, ammaa has a LH pattern: sai, har and koo began a new downdrift pattern at a higher pitch than would have been predicted in Chapter 2. Ammaa results in a curve on the phrase it initiates such as those shown in Figure 3.13 lines a and b. Figure 3.13 is the pitch curves of the sentences in (19):

- (19) a. Yaa shìga gidaa àmmaa yaa fìta jiyà.
 'He went into the house but he came out yesterday.'
- b. Zàn tàfi àmmaa zàn daawoo.
 'I'm going but I'll come back.'

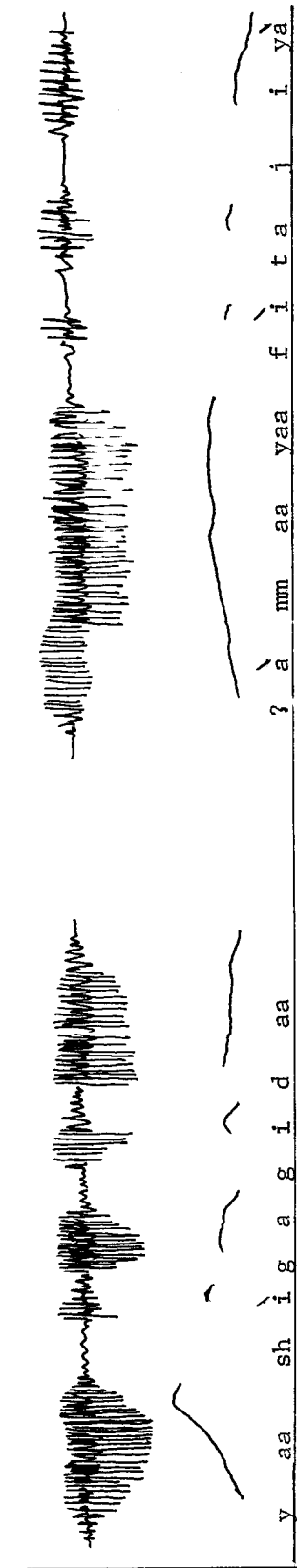
In both of these utterances the conjunction ammaa starts a new intonation contour. In line (a) the first syllable of ammaa is at the same pitch as the preceding lowered high tone, but the high tones which follow the conjunction rise to a pitch as high as the raised high tone on yaa. This second pitch curve would not have been predicted by the rules in Chapter 2. In line (b), the initial syllable is slightly higher than the preceding lowered high tone, but it is the high curve throughout the phrase that shows that this is a separate pattern. It is possible that the utterances in (19 a and b) would be properly analyzed as being composed of two sentences, the second, naturally, having its own separate intonation contour.

3.4.2 Exclamations

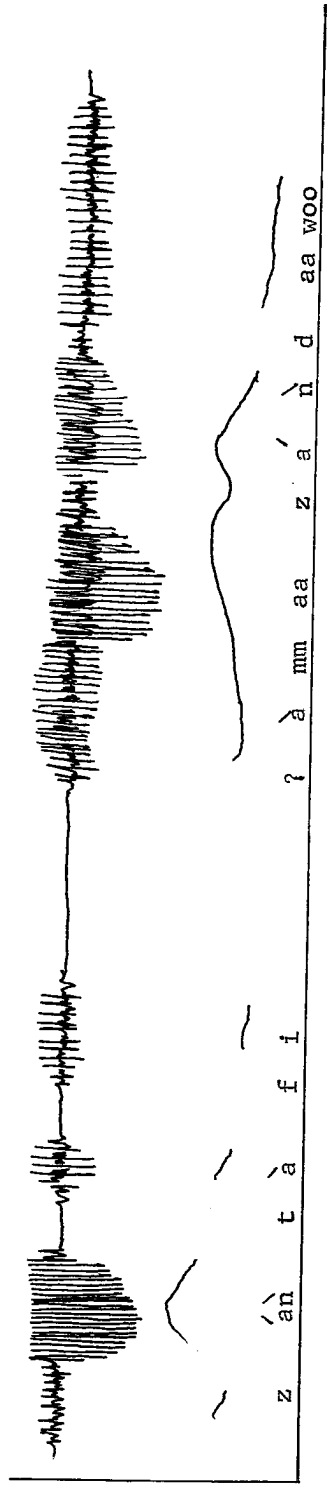
In Figure 3.14, the pitch curves and wave forms of two Hausa utterances containing exclamations are given:

- (20) a. Àshee, jàkar kudii cèè.
 'Wow, it's a bag of money!'
- b. Audù yaa céè, 'Káì, mun yi saa'àa.
 'Audu said, "Boy, we lucked out!"

In line (a), the exclamation has a very extreme pitch contour; the initial syllable of the word àshee is at 100 hz, the second syllable falls from 160 hz to 110 hz. In line (b), the exclamation, káì, falls from 140 hz to 84 hz. Both of these words should have a feature in the lexicon [+exclamatory] in order that they undergo a rule assigning them extreme pitch contours relative to the pitch contours of the utterances of which they are a part. Since this investigation is so superficial and it is not known how what pitch contours these and other exclamations are assigned, no rule of pitch assignment for exclamations will be formulated here.

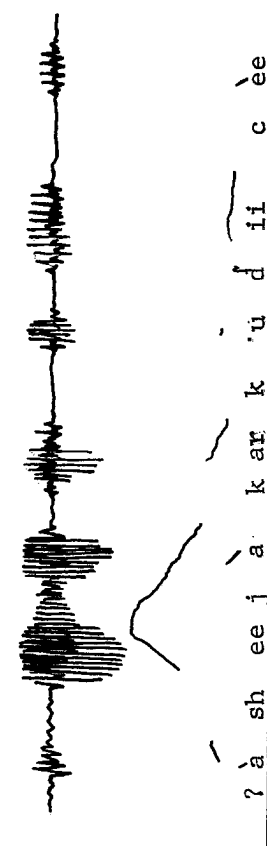


a. Yaa shì g a g i d aa, à m m a a yaa f i t a j i yà.
 'He entered the house, but he went out yesterday.'

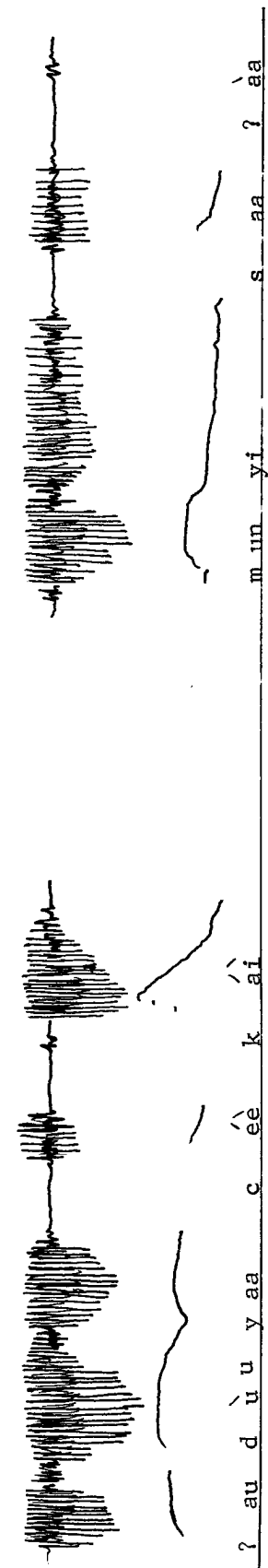


b. Z à n tà f i , à m m a a z à n d a a w o o .
 'I will leave, but I'll return.'

Figure 3.13: Pitch curves and wave forms of two utterances with the conjunction à m m a a 'but'. The utterances each have two intonation contours.



a. Àshee, jàkar kudii cèe!
 'Wow, it's a bag of money!'



b. Auduu yaa cèe, 'Kai mun yi saa'aa."
 'Audu said, "Boy, we lucked out.'

Figure 3.14: Pitch curves and wave forms of utterances with the exclamations àshee and kai.

3.5 Conclusions

In this chapter the effects of syntax and semantics on the pitch patterns of Hausa utterances were investigated. It was found that, for the most part, major constituent breaks were not marked by any unusual pitch perturbations, and it was concluded that it is improbable that pitch perturbations are used as cues for surface constituent structure.

Interrogatives were found to have different pitch realizations from statements, and these pitch realizations differed from traditional descriptions in the literature. Yes-no questions were characterized by raised pitch throughout the utterance, not just on the final high tone, or final syllables. It was not possible from the limited data gathered for this chapter to determine exactly at what point in the utterance the interrogative raised pitch began. In question-word questions the entire clause containing the questioned constituent was usually raised to a higher pitch. The pitch patterns of the rest of the question-word questions varied. In some cases, only the questioned clause was raised and the rest of the utterance was downdrifted, in other cases, the final high tone(s) of the question-word question was raised. It was suggested that an interesting question for future research would be to determine how differences in the scope of the interrogative affects the pitch realization of question-word questions.

It was found that the Hausa identifier particle, nee/cee, while underlyingly polar in tone, was realized with the pitch predicted by the rules in Chapter 2.

Finally, lexical items which might be expected to perturb the downdrift patterns of utterances were analyzed. It was found that the modal operators, koo, sai, and har perturbed the downdrift pattern, starting a new pattern, only when they interrupted the scope of a preceding modal. Àmmaa started a new downdrift pattern, but it was suggested that ammaa might be analyzed as starting a separate sentence. As would be expected, the exclamations kai and àshee had more extreme pitch realizations than the other lexical items. It is obvious that all these lexical items will have to be assigned features in the lexicon which interact with rules of pitch assignment so that they are assigned extreme pitch.

Because of the paucity of data analyzed in this chapter, no attempt was made to formalize these findings to incorporate them into the grammar.

FOOTNOTES

1

Koo interacts with other modals which express the speaker's commitment to the truth of the propositions within their scope in predictable ways. Koo may not occur in subject position (because of the factivity of this position in Hausa), and it may not conjoin the objects of factive verbs with first person subjects, in the perfective or imperfective. When koo occurs within the scope of maa, 'in fact, indeed', a strong speaker assertion particle, or in asserted rhetorical questions, or in counterfactual or even though conditionals, it is modified in meaning from speaker uncertainty to speaker unexpectedness that the proposition within its scope is true. In these latter cases, koo occurs within the scope of a more powerful factive modality in that the factive modal requires an interpretation of assertion on the part of the speaker and koo is reduced to having an interpretation of surprise instead of uncertainty.

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