AN ACOUSTIC STUDY OF 'TONAL ACCENT' IN CREEK

JACK B. MARTIN AND KEITH JOHNSON

COLLEGE OF WILLIAM AND MARY AND OHIO STATE UNIVERSITY

1. Introduction. Creek word prosody has received impressionistic phonetic description and occasional phonological attention, but to our knowledge has never been studied instrumentally.[1] Haas (1977a) treated word prosody in terms of 'tonal accent': the assignment of one of three phonemic tones to key syllables. Subsequent descriptions have attempted to reduce one of these tonal accents to stress. This paper reports acoustic findings obtained in a study of eight speakers (4 male and 4 female) of the Muskogee dialect of Creek. Creek word prosody displays declination and a phenomenon we refer to as 'tone spacing' (measured downstep). **2** provides a summary of Haas's description and more recent, metrical approaches. **3** presents the results of our acoustic study.

2. Haas's 1977 description. The first modern linguistic descriptions of Creek resulted from field work conducted by Mary R. Haas from 1936 to 1940, and again briefly in 1969. Haas's studies led to a phonemic inventory of the consonants and vowels (Haas 1940) and, most pertinent to this study, a detailed description of pitch (Haas 1977a). **2.1** discusses her phonemic analysis of pitch. **2.2** discusses her assignment of phonetic values.

2.1 Haas's phonemic description. Haas (1977a) analyzes Creek as having a system of 'tonal accent': every word larger than a light monosyllable will have at least

one ‘key syllable’ that determines the pitch of the entire word. Each key syllable will further have one of three phonemic tones (Haas 1977a:197): level (˝), falling (ˆ), or extra high or slightly rising and crescendo (ˇ) (henceforth, 'rising').

Uninflected forms (nouns, infinitives, etc.) generally only have the level accent:[2]

(1) *ifá* 'dog'

wá:ka 'cow'

apo:kitá 'to sit (of three or more)'

Inflected forms may have any of the three tonal accents, with different tonal accents signaling differences in aspect:

(2) *apó:ki:s* 'we are (here)'

apô:ki:s 'we are sitting down, are in a sitting position'

apǒ:^{n}ki:s 'we keep sitting and sitting'

The level tone accent pattern in uninflected forms (as in (1)) is the simplest. Haas (1977a:202-4) describes this pattern as follows:

(3) a. In a string of light syllables containing no fixed accents, level tone will be placed on the last even-numbered syllable:[3]

ifá ‘dog’

ifóci ‘puppy’

amifocí ‘my puppy’

b. If the penult is a heavy syllable and the ultima is light, level tone will be placed on the penult:

cá:lo ‘trout, bass’

sókca ‘sack, bag’

pocóswa ‘axe’

c. In a string of light syllables following a heavy syllable, level tone will be placed on the last even-numbered syllable:

aktopá ‘bridge’

wa:kocí ‘calf’

alpatóci ‘baby alligator’

d. If the ultima is a heavy syllable, level tone will normally be placed on that syllable:[4]

fó: ‘bee’

hoktí: ‘woman’

Several phonologists have since examined the range of data in (3) and concluded that the placement of level tone accent in nouns and uninflected verbs in Creek has the properties of an iambic stress system (even though ‘stress’ here is realized as pitch). Halle and Vergnaud (1978, cited in Hayes 1995) were apparently the first to realize this; other treatments since have included Jackson (1987) and Hayes (1995:64-67), among others.

Each of these more recent treatments makes use of the iamb: if possible, a disyllabic foot is formed in which the first syllable is light and the second syllable is light or heavy, but stressed; if the first syllable is heavy, a monosyllabic stressed syllable is formed. Iambic feet of this type are formed from left to right in Creek, giving structures like the following for the forms in (3):

(4)

(. x)	(. x)
ifá ‘dog’	ifóci ‘puppy’
(. x)(. x)	(x)(. x)
ami focí ‘my puppy’	alpatóci ‘baby alligator’
(x)(x)	(x)
hoktí: ‘woman’	fó: ‘bee’

From the forms in (4), it is evident that Haas’s level tone accent occurs on the last stressed syllable in the word. This leads Hayes (1995) to posit final word-level stress in such forms:

(5)

```
(  x)                    (  x)
(. x)                    (. x)
 ifá  ‘dog’               ifóci  ‘puppy’

(       x)               (     x)
(. x)(. x)               (x)(. x)
 ami focí  ‘my puppy’     alpatóci  ‘baby alligator’

(   x)                   (x)
(x)(x)                   (x)
hoktí:  ‘woman’          fó:  ‘bee’
```

We will follow Hayes in assuming that Creek has left-to-right iambic feet and final word-level stress, at least in uninflected forms. We do not mean by this that stressed syllables are necessarily louder or longer than unstressed syllables, but that syllables are organized rhythmically into higher units, and pitch is one cue of that organization.

The various patterns associated with inflected forms (as in (2)) are more complex. Generally, tonal accent is assigned to the last syllable of the stem (*apo:k-* in (2)) as a result of 'ablaut' or 'grades' (Haas 1940). We will not describe the phonology of this system here, instead concentrating on its phonetic realizations.

2.2 Haas's phonetic description. To describe the phonetics of Creek pitch, Haas (1977a) establishes a descending scale from 1 (highest) to 5 (lowest). Initial light nonkey syllables are described as having a pitch that is slightly lower than the pitch of the following syllable, so to obviate a specific pitch value, she uses i (‘initial’) for syllables of this type. Similarly, medial light syllables may be lowered in certain circumstances

and are assigned the value m (‘medial’), and final syllables are described as d (‘deep’), the lowest pitch in a word. She then proposes the following phonetic values for key syllables:

(6) a. an initial light syllable will have pitch i; any other pretonic syllable will have pitch 3;

b. ˊ is 2 if first and nonultimate; 3 if first and ultimate.

c. ˆ is 24 if first and nonultimate; 2d if first and ultimate.

d. ˅ is 21 or 1 if first and nonultimate.

e. a posttonic syllable has the lowest pitch, marked d

The forms in (7) are examples of these values:

(7) *isíta* i-2-d ‘one to take one’

apataná i-3-3-3 ‘bullfrog’

nafkitá 3-3-3 ‘one to hit one’

fó: 3 ‘bee’

nâ:ki 24-d ‘something, anything, what’

ci:kôlko 3-24-d ‘purple martin’

hatâm i-2d ‘again’

nă:^{n}fkeys 21-d (or) 1-d ‘I kept hitting’

Haas (1977a:200) further notes that a process of 'downward drift' (downstep) applies between key syllables:

> Each nonfirst key syllable will be pitched one step lower than the immediately preceding key syllable. Thus if the first key syllable is 2, 24, or 21, the second will be 3, 35, or 3d (ultima).

Examples of this process appear in (8):

(8) *pó:fká:ks* 2-3 'they are blowing (with mouth)'
náfka:kêys 2-3-3d 'they were hitting him'
sâ:sákwa 24-3-d 'goose'
atǒ:ntkíccíká:ɬi:s i-21-3-4-5-d 'you will not be working regularly, constantly'

3. An acoustic study of Creek pitch.

3.1 Methodology. An acoustic study of Creek pitch (voice fundamental frequency or F0) was conducted in conjunction with a study of Creek segmental phonemes (Johnson and Martin 2000). We sought: 1) to establish instrumentally the phonetic correlates of contrasts in accent placement and accent type (level, falling, rising) that Haas observed; and, 2) to examine the fit between Haas's impressionistic phonetic description and our acoustic data.

Eight speakers (4 women and 4 men) participated in the study. All were native speakers of the Muskogee dialect who use the language routinely. Their ages ranged from the early 50s to the late 80s at the time of recording.

A word list demonstrating various contrasts (vowels, consonants, word and sentence prosody) was constructed. Only the portion of the word list dealing with word prosody was used in this study.

The speakers were recorded in groups of two to four speakers. Because some of the speakers were not literate in Creek, we asked Margaret Mauldin, a Creek speaker who is literate in her language, to read the target word first as a prompt. The other speakers were instructed not to imitate her, however, and our impression is that they did not. Two repetitions of the word list were recorded for each speaker in each session.

Six speakers were recorded with a Shure SM48 hand-held unidirectional microphone (passed from speaker to speaker during the recording session) and a Marantz PMD 222 portable cassette recorder. One speaker was recorded using a Shure SM10 head-mounted microphone, and one speaker was recorded using a Realistic lavaliere microphone and a Marantz PMD 430 portable cassette recorder.

The acoustic analysis was done in five steps: First, the recordings were digitized with a sampling rate of 16 kHz with 16 bit accuracy. An antialiasing decimation filter removed frequency components above 8 kHz. Second, each word was digitally edited from the longer recording and stored in a separate computer file. Third, the temporal locations of vowel onsets and offsets were noted on the basis of aligned spectographic and waveform displays in a wave form editing program (Entropic XWaves). Fourth, the fundamental frequency of voicing was calculated by an algorithm that uses the

normalized cross-correlation function and dynamic programming (Talkin1995). Estimates of voice F0 were calculated at 10 ms intervals throughout the word. Fifth, F0 values and time values were extracted from the raw F0 data file at three times in each of the vowels in the word: vowel midpoint (50% of the vowel duration) and at 20% and 80% of the vowel duration. Finally, mistracked F0 values were corrected by hand. The number of F0 tracking errors so corrected was relatively small (228/4389=5.2%).

The following subsections discuss the results of our study. **3.2** is an overview of the surface contrasts. **3.3** details the acoustic correlates of tonal accent.

3.2 Surface contrasts in word prosody. We will first attempt to establish the surface contrasts in word prosody observed by Haas (1977a). Figure 1 shows the verb stem *leyk-* 'sit (of one)' in different grade forms to demonstrate near minimal contrasts between Haas's level tone, falling tone, and rising tone, respectively, in initial position in disyllabic words. Haas's predicted phonetic values for each syllable are given in each figure.

Figure 1. Average F0 patterns of the words *léyhkeys* 'I sat down (just now)', *lêykeys* 'I'm sitting down', and *lěy^{n}keys* 'I keep sitting and sitting' demonstrating the prosody of level, falling, and rising tone accent in initial position. '2 - d', '24 - d', etc. indicate Haas's predicated phonetic values.

These traces are in accord with Haas's description, showing steady pitch, a slight fall, and a rise on the first syllable of these words. Figure 1 also shows wide differences in vowel

length in the accented syllable: in *léyhkeys*, syllable-final /h/ acts to shorten the preceding diphthong; in *lěy^{n}keys*, nasalization has the effect of lengthening the preceding diphthong.

Figure 2 uses the same verb stem to demonstrate minimal contrasts between level and falling tone accent in final position.

Figure 2. Average F0 patterns of the words *leykéys* 'I'm in the process of sitting down' and *leykêys* 's/he can sit' demonstrating the prosody of level and falling tone accent in final position..

The contrast in the three accent patterns in perhaps clearest in medial position. Figure 3 contrasts these patterns in the penultimate syllable of four-syllable words (derived in these examples from *awanay-* 'to tie to').

Figure 3. Average F0 patterns of the words *awanáhyis* 's/he tied him/her to it (just now)', *awanâ:yis* 's/he has tied him/her to it', and *awană:^{n}yis* 's/he has tied him/her to it' demonstrating the prosody of level, falling, and rising tone accent in medial position.:

Further contrasts in word prosody result from differences in the placement and number of tonal accents. Figure 4 shows additional forms of *awanay-* 'tie to' with level tone accent on the last syllable rather than on the penult and with two level tone accents (the first triggering downstep).

Figure 4. Average F0 patterns of the words *awanayás* ‘tie him/her to it’ and *awána:yís* ‘s/he is tying him/her to it’. A comparison with Figure 3 demonstrates contrast in placement and number of level tone accent.

Comparing Figures 3 and 4, we see that four-syllable forms can have as many as five contrasting accent patterns. This is because the three tonal accents can co-occur and occur in different positions.

As noted in **2.1**, uninflected forms show fewer contrasts: the vast majority of nouns have only level tone accent (placed according to the iambic rule discussed there); a handful of nouns have falling tone accent; no basic nouns are known to have the rising tone accent. Figure 5 shows contrasts in two-syllable nouns between level and falling tone accent; Figures 6 and 7 show the same contrast in three-syllable nouns.

Figure 5. Average F0 patterns of the words *wá:ka* ‘cow’ and *nâ:ki* 'something' demonstrating the prosody of level and falling tone accent in two-syllable nouns.

Figure 6. Average F0 patterns of the words *ancokó* ‘my house’ and *ânɬawá* ‘wilderness’ demonstrating the prosody of level and falling tone accent in three-syllable nouns.

Figure 7. Average F0 patterns of the words *i:fkánco* ‘tick’ and *hî:spákwa* ‘robin’ demonstrating the prosody of level and falling tone accent in three-syllable nouns.

A further contrast noted by Haas results from the deletion of initial syllables. Initial unaccented syllables--particularly light ones--are slightly lowered in Creek. A word like *ací* ‘corn’ thus has an initial syllable that is pitched slightly lower than the following, accented syllable. Initial syllables (particularly initial /i/) are sometimes deleted, however. The word *iháci* ‘its tail’ is thus normally pronounced *háci*. Deletion of initial syllables leads to surface contrasts in pitch, as shown in Figure 8.

Figure 8. Average F0 patterns of the words *ací* ‘corn’ and *háci* (<*iháci*) ‘its tail’ demonstrating surface contrasts resulting from loss of initial syllables.

Longer words show a similar contrast: the word *yanása* ‘buffalo’ thus shows lowering of the initial light syllable, while *’yanawá* (<*iyanawá*) ‘his/her cheek’ shows no lowering (Figure 9).[5]

Figure 9. Average F0 patterns of the words *yanása* ‘buffalo’ and *’yanawá* (<*iyanawá)* ‘his/her cheek’ demonstrating surface contrasts resulting from loss of initial syllables.

It is evident from a comparison of Figures 8 and Figures 9 that Creek nouns show surface contrasts in the placement of level tone accent and in initial lowering, though these are not underlying contrasts.

3.3 The phonetics of Creek word prosody revisited. The Average F0 patterns in **3.2** provide support for Haas's claim that there are three types of tonal accent in Creek and that further patterns of word prosody result from placement and multiple occurrence of these accents. We turn in this section to the phonetic realization of the three accents as a result of context.

3.3.1 Level tone accent. Haas (1977a) states that level tone accent is 2 if first and nonultimate, and 3 if first and ultimate. Examples relevant to this claim are Figures 1a, 2a, 3a, 4a-b, 5a, 6a, 7a, 8a-b, and 9a-b.[6]

Based on our data, we do not find an ultimate/nonultimate asymmetry in the realization of level tone accent. Instead, we see a graded declination in the value of level tone accent from initial syllables (where it is roughly 175-180 Hz in Figures 1a, 8b) to final syllables (where it is roughly 155 Hz in Figures 2a, 4a, 6a, 8a, 9b). Medial instances have values in between (roughly 160 Hz in Figures 3a, 7a, 9a). This declination is most obvious when words like *háci* 'its tail' and *ací* 'corn' are contrasted, as in Figure 8.

Another place where our data diverge from Haas's description is words of the shape (C)V:CV (e.g., *wá:ka* 'cow' in Figure 5a). We find that this word (and to our ears, all words of this shape) have a low, slightly rising pitch on the penult (moving from

roughly 150 to 160 Hz). This pattern is in sharp contrast to words like *léyhkeys* 'I sat down (just now)' in Figure 1a or *háci* 'its tail' in Figure 8b where it is 175-180 Hz.

3.3.2 Falling tone accent. Haas (1977a) describes falling tone accent as 24 if first and nonultimate; 2d if first and ultimate. Relevant data in our study are presented in Figures 1b, 2b, 3b, 5b, 6b, and 7b.

Our data diverge somewhat from Haas's description. We find that falling tone accent in word-initial position is either rising falling (Figure 1b, possibly 6b, 7b) or falling (Figure 5b), but not as dramatically falling as Haas predicts. In medial or final position it is falling (Figures 2b, 3b).

As with level tone accent, we find graded declination in the word: in initial position (Figures 1b, 5b, 6b, 7b), the peak of falling tone accent is at about 175 Hz. In medial position (Figure 3b) or final position (Figure 2b), the peak is at about 160 Hz.

3.3.3 Rising tone accent. Haas (1977a) describes rising tone accent as 21 or 1 if first and nonultimate. Relevant data in our study are found in Figures 1c and 3c. In each case, rising tone accent begins at about 150 Hz and peaks at about 180 Hz. It is not clear from these two examples whether declination affects rising tone accent.

3.3.4 Downstep and tone spacing. In **3.3.1** and **3.3.2** we established that the pitch values associated with level and falling tone accent decline from initial to final position in words. Haas (1977a) observes a separate process of 'downward drift' applying in words with more than one key syllable. According to her description, the

second key syllable in a word is pitched one level lower than the first key syllable, the third key syllable is pitched one level lower than the second key syllable, etc. Thus, if level tone accent receives the value of 2 when first, it receives the value of 3 if second and 4 if third.

The data in Figure 10 support Haas's claim.

Figure 10. Average F0 patterns of the words *nafkaká·i:s* 'they will hit him/her' and *náfkaká·i:s* 'we will hit him/her', with one and two level tone accents, respectively.

In Figure 10a, the first accented syllable has a pitch of about 160 Hz. In Figure 10b, the first accented syllable has a higher pitch of about 195 Hz. Part of the difference between the two can be attributed to declination: we have shown that level tone accent has a higher realization in initial position than in medial position. Note, however, that the pitch of third syllable differs slightly in the two forms in Figure 10, with a value of about 160 Hz in Figure 10a and about 150 in Figure 10b. This difference, while subtle, cannot be due to declination because in both cases it is the third syllable of the form; instead, the lower value in Figure 10b appears to result from a preceding accent, as Haas predicts. Our data are thus consistent with the claim that Creek has downstep.

When we look at more complicated examples, however, we find that the specific values assigned to accented syllables diverge from Haas's predictions. Figure 11 adds a word with three level tone accents to the forms in Figure 10.

Figure 11. Average F0 pattern of the word *náfkícká↯i:s* ‘you will hit him/her’, with three level tone accents, contrasted with the forms from Figure 10.

At first the terraced effect seen in Figure 11a appears to be clear evidence of downstepping. When we compare this pattern to those in Figures 11b-c, however, we see that there are differences between the two. Specifically, the second accented syllable of *náfkícká↯i:s* (11a) is higher in pitch that the second accented syllable of *náfkaká↯i:s* (11b). In studying these figures carefully, we conclude that the pitch range is evenly divided based on the number of accents: when there are two level tone accents, the second is intermediate between the high and low values; when there are three, the second and third are again spaced evenly between the high and low values. Instead of describing the phenomenon as simple downstepping, then, one might more accurately describe it as downstepping with *tone spacing*.

3.3.5 Nonkey syllables. As noted in **2.1**, Haas (1977a) distinguishes between *key syllables* (syllables with tonal accents) and *nonkey syllables* (syllables whose pitch is determined in relation to key syllables). Her description of the pitch of nonkey syllables is paraphrased in (9) (Haas 1977a:201ff):

(9) a. An initial light nonkey syllable will have the pitch she calls 'i' (i.e., a value slightly lower than the pitch of the following syllable). Thus, *hicíta* ‘to see’ has a pitch of i-2-d.

b. Any other pretonic light syllable and any pretonic heavy syllable will have pitch 3. Thus, *wanayitá* 'to tie' has a pitch of i-3-3-3.

c. A nonultimate intertonic (between key syllables) heavy syllable will have the pitch of the next level key syllable while a light syllable in the same position will have that pitch or m pitch (slightly lowered relative to the following syllable). Thus, *atǒ:^{n}tkiyáɬi:s* 'we will keep on working' has a pitch of i-21-m-3-d. When the next key syllable is a falling tone accent, a heavy or light syllable will be one step below the high part of the falling key syllable.

d. Posttonic light or heavy syllables have pitch d (the lowest pitch). Thus, *nafêykíckis* 'you hit him/her' has a pitch of i-24-3-d.

Our own data suggest a slightly different picture, and one that can be simplified by reference to iambic feet (**2.1**):

(10) a. Iambic feet are assigned left to right in all forms.

b. Pitch forms a plateau beginning with a stressed syllable and extending rightward to the next key syllable; the pitch of the plateau assumes the pitch of the initial portion of the key syllable (Figures 2a,b, 3a,b,c, 4a, 9b, 10a, less clearly in 6a,7a).

c. Initial unstressed syllables show slight lowering ('inclination') of about 10 Hz (Figures 3a,b,c, 4a,b, 8a, 9a, 10a).

d. There is a drop from the last key syllable to the end of the word. In inflected forms (where sentence prosody may play a greater role), this drop descends to about 110 Hz (Figures 1a,b,c, 3a,b,c, 10a,b, 11a); in uninflected forms (nouns, infinitives, etc.), the drop is to about 145 Hz (Figures 5b, 6b, 7a,b, 8b, 9a).

To see the effects of (10), we can return to the surface contrast between *yanása* ‘buffalo’ and *’yanawá* (<*iyanawá*) ‘his/her cheek’ from Figure 9. We assume that the underlying representations of these words are /yanasa/ and /iyanawa/. Iambic feet are formed left to right as in (11):

(11)

```
(. x)                    (. x)(. x)
yanasa  ‘buffalo’         iya nawa  ‘his/her cheek’
```

Final word-level stress is assigned to the last foot, where level tone accent is assigned:

(12)

```
(  x)                    (       x)
(. x)                    (. x)(. x)
yanása  ‘buffalo’         iya nawá  ‘his/her cheek’
```

In medial position (as in ‘buffalo’), level tone accent has a value of about 160 Hz. In final position (as in ‘his/her cheek’), it has a value of about 155 Hz. By (10c), the initial unstressed syllables of ‘buffalo’ and ‘his/her cheek’ are lowered slightly. By (10b), a plateau in pitch is formed in ‘his/her cheek’ from the first stressed syllable to the key syllable, assuming a value in this case of about 155 Hz. The initial vowel in *iyanawá* may delete, but the metrical structure (and the pitch that is tied to it) remains the same.

3.4 Other cues of tonal accent. As noted in **2.1**, level tone accent in Creek differs from the two other tonal accents in having the basic phonological properties of an iambic stress system. Haas (1977a) treats all three accentual phenomena together,

however, and describes these phenomena purely in terms of pitch. The question arises as to whether level tone accent--analyzed phonologically as stress--differs in duration or amplitude from falling or rising tone accent.

If we compare the second syllable of the forms in Figure 4, we see that level tone accent has no affect on a vowel's duration. Indeed, the primary cue of the first accent in Figure 4b appears to be the downstep it induces on the third syllable. Similarly, although the first syllable of the two forms in Figure 8 and the second syllable of the forms in Figure 9 differ in accent and pitch, they do not differ appreciably in duration.

We have not yet examined the affect of accent on amplitude. Based on the findings presented here, however, we agree with Haas that the primary cue of level tone accent, like falling and rising tone accent, is in terms of pitch. At the same time, its phonological properties clearly set it apart.

4. Conclusion. Creek is an example of a language in which word prosody is determined by key syllables assigned one of three accents (˝, ^, ˇ), the primary cues of which are in terms of pitch. Of these tonal accents, level tone accent (˝) appears to be best analyzed phonologically as 'stress': positing iambic feet is useful not only for the distribution of this accent, but for assigning pitch to nonkey syllables.

We have used acoustic measurements in this paper to verify the contrasts observed by Haas (1977a), to provide a more precise characterization of word prosody in Creek, and to motivate the existence of declination and downstep (or more precisely, downstep with tone spacing) in the language. It remains to be seen how the word prosody described in this paper is to be treated within a larger theory of sentence prosody.

[1] The phonemes used in this paper follow Haas (1940, 1977b). The vowels are short /a, i, o/ and long /a:, i:, o:/; /e/ results when /a/ is raised before tautosyllabic /y/. The consonants are /c f h k l ɬ m n p s t w y/. /c/ is an alveo-palatal affricate; /ɬ/ is a voiceless lateral fricative. /^{n}/ represents nasalization. We are grateful to Margaret Mauldin for assisting us in interviewing Creek speakers, to Lara Taylor for her help in analyzing the data in this paper, and to the National Science Foundation (under grant SBR-9809819) for its support of research on Creek.

[2] A handful of nouns (e.g., *nâ:ki* 'something') have falling tone accent.

[3] Light syllables for Haas (1977:196) are those that end in short vowels.

[4]Here we differ from Haas. Haas (1977:204) claims that accent is no longer automatic when the ultima is heavy, citing contrasts like the following:

(i) *hátk-i:* 'white'

hoktí: 'woman'

It seems preferable to analyze the suffix *-i:* in 'white' as outside the domain of accent placement.

[5]Haas places an apostrophe before a word-initial light syllable to signal that the following light syllable is not lowered.

[6] 'Figure 1a' refers to the first word in Figure 1.

REFERENCES

HAAS, MARY R. 1940. Ablaut and its function in Muskogee. Language 16:141-50.

_____. 1977a. Tonal accent in Creek. Studies in Stress and Accent, ed. Larry M. Hyman. Southern California Occasional Papers in Linguistics 4:195-208. Los Angeles: University of Southern California. Reprinted 1987 in A Creek Source Book, ed. William C. Sturtevant. New York: Garland Publishing.

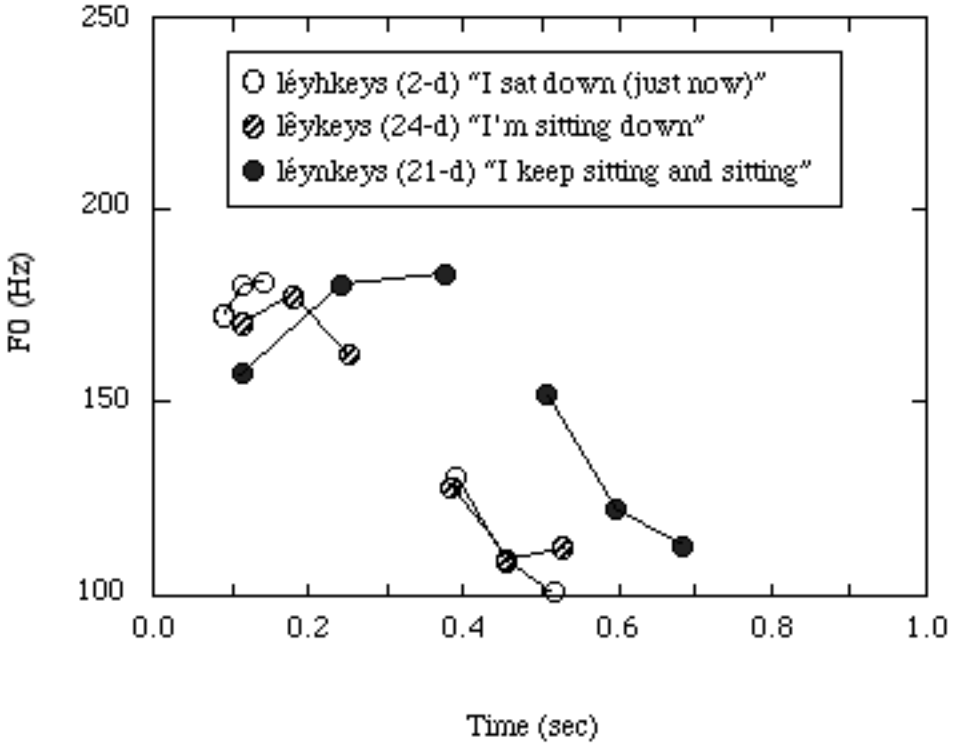
_____. 1977b. Nasals and nasalization in Creek. Proceedings of the Third Annual Meeting of the Berkeley Linguistics Society, ed. Kenneth Whistler, et al., 194-203. Berkeley: University of California, Berkeley.

HAYES, BRUCE. 1995. Metrical Stress Theory: Principles and Case Studies. Chicago/London: University of Chicago Press.

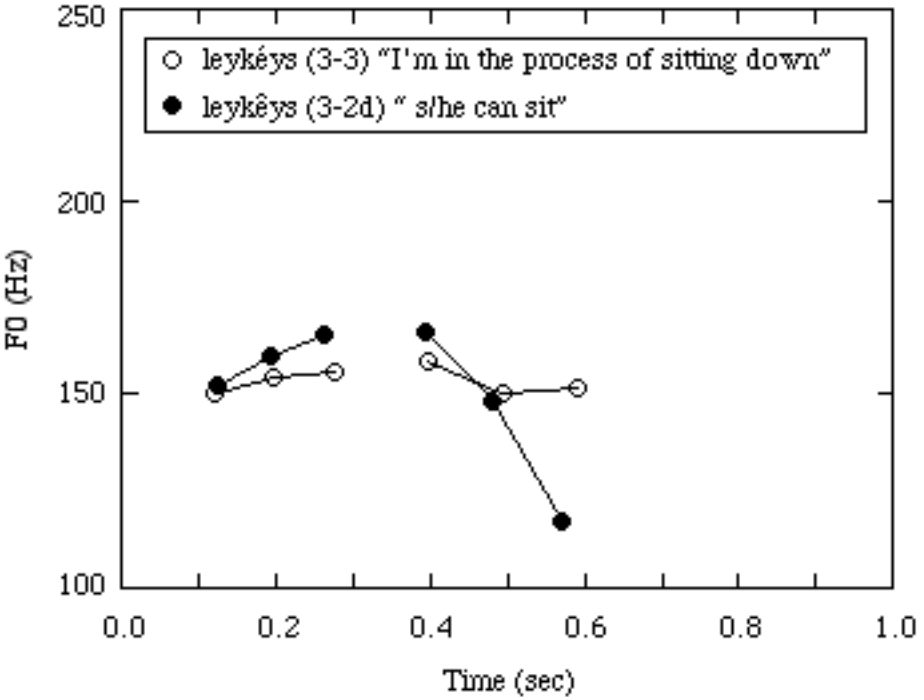
JACKSON, MICHEL. 1987. A metrical analysis of the pitch accent system of the Seminole verb. Muskogean Linguistics, ed. Pamela Munro, 81-95. UCLA Occasional Papers in Linguistics 6. Los Angeles: UCLA Department of Linguistics.

JOHNSON, KEITH, AND JACK B. MARTIN. 2000. Acoustic vowel reduction in Creek: Effects of distinctive length and position in the word. Phonetica (to appear).

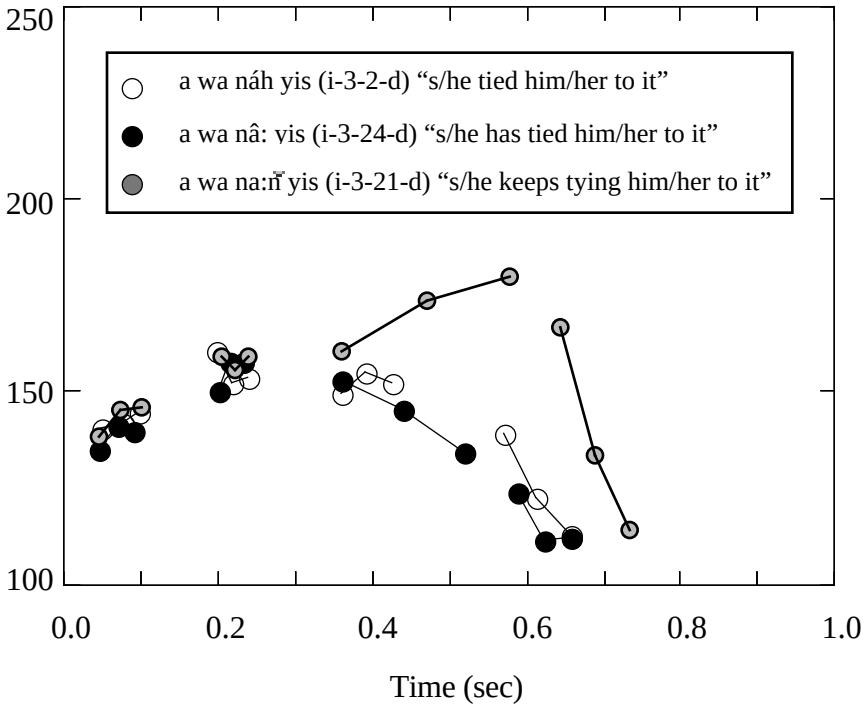
TALKIN, D. 1995. A Robust Algorithm for Pitch Tracking (RAPT). Speech Coding and Synthesis, ed. W. B. Kleijn and K. K. Paliwal. NewYork: Elsevier.

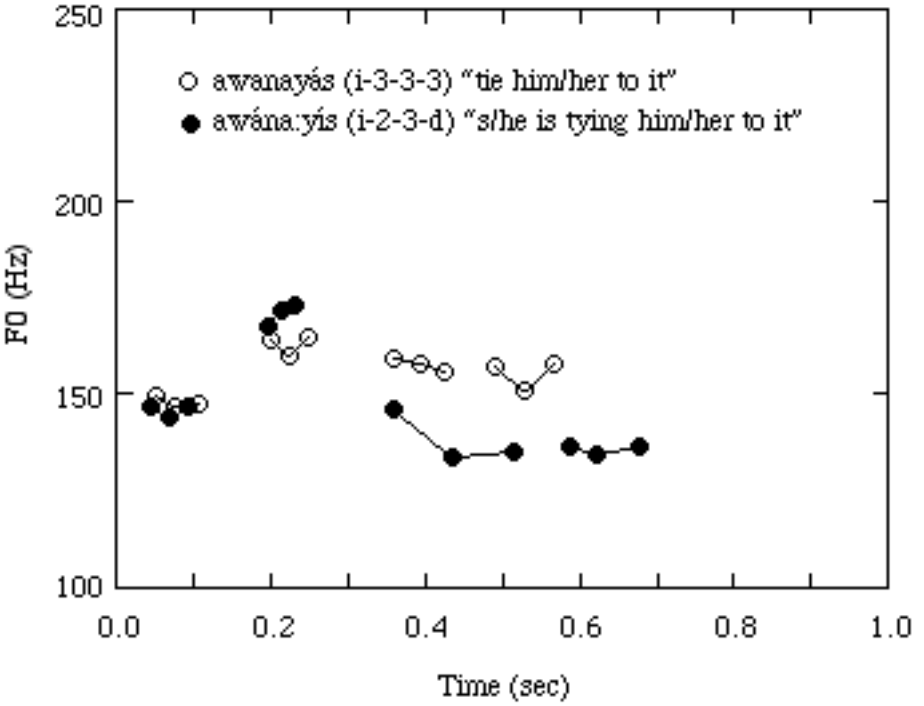


Martin & Johnson, Figure 1

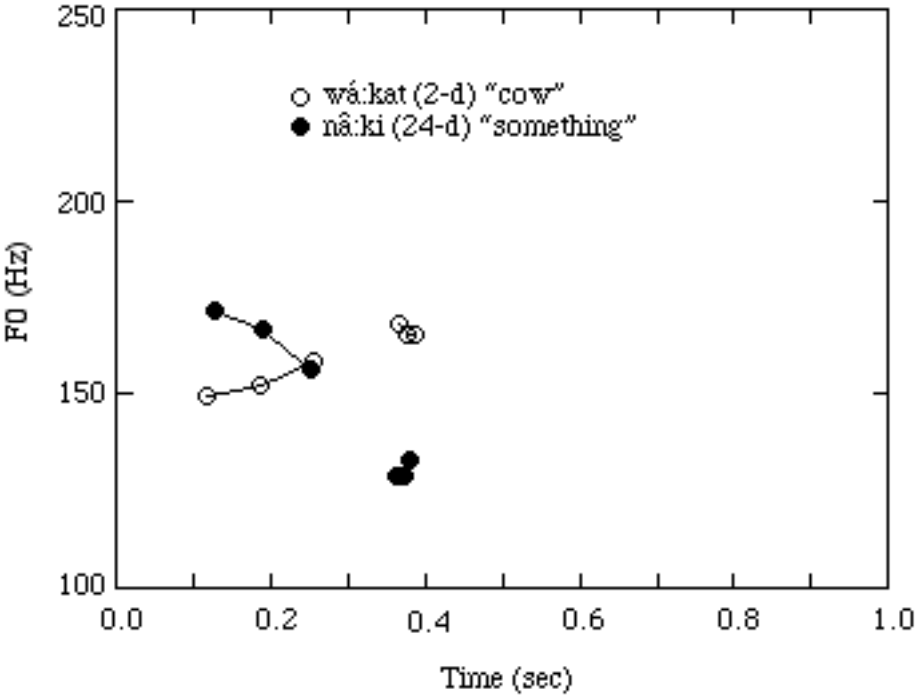


Martin & Johnson, Figure

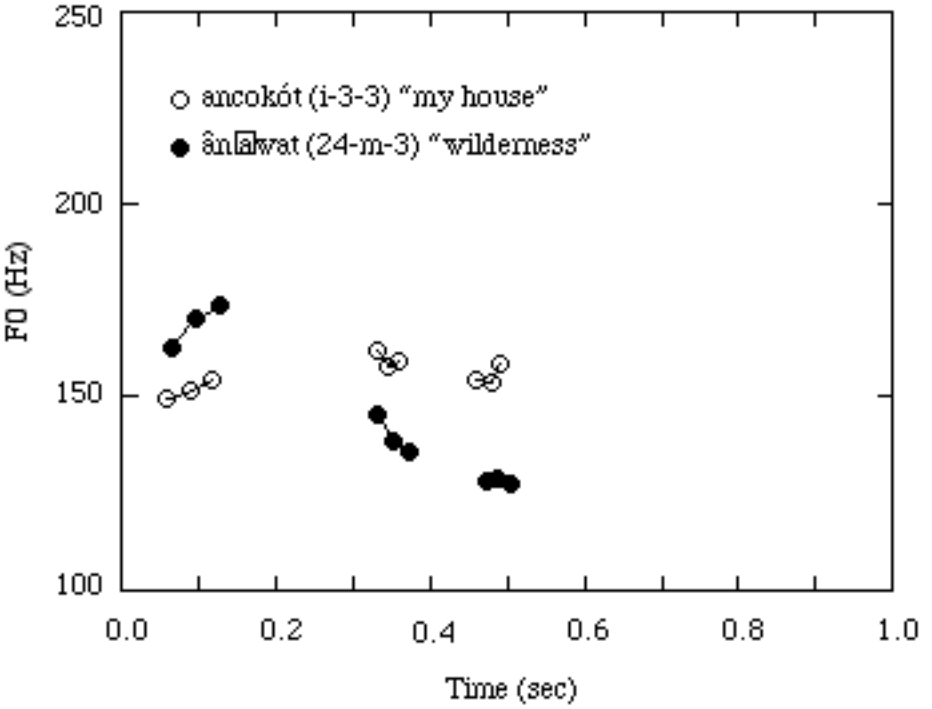

250
200
150
100
0.0
0.2
0.4
0.6
0.8
1.0
Time (sec)
a wa náh yis (i-3-2-d) “s/he tied him/her to it”
a wa nâ: yis (i-3-24-d) “s/he has tied him/her to it”
a wa na:n̆ yis (i-3-21-d) “s/he keeps tying him/her to it”



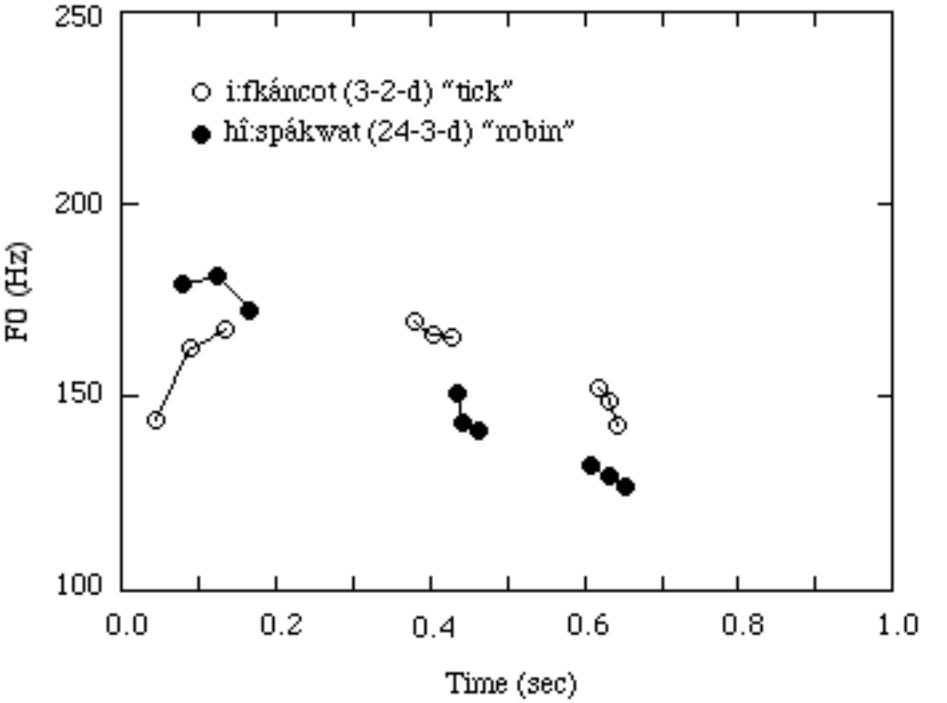
Martin & Johnson, Figure



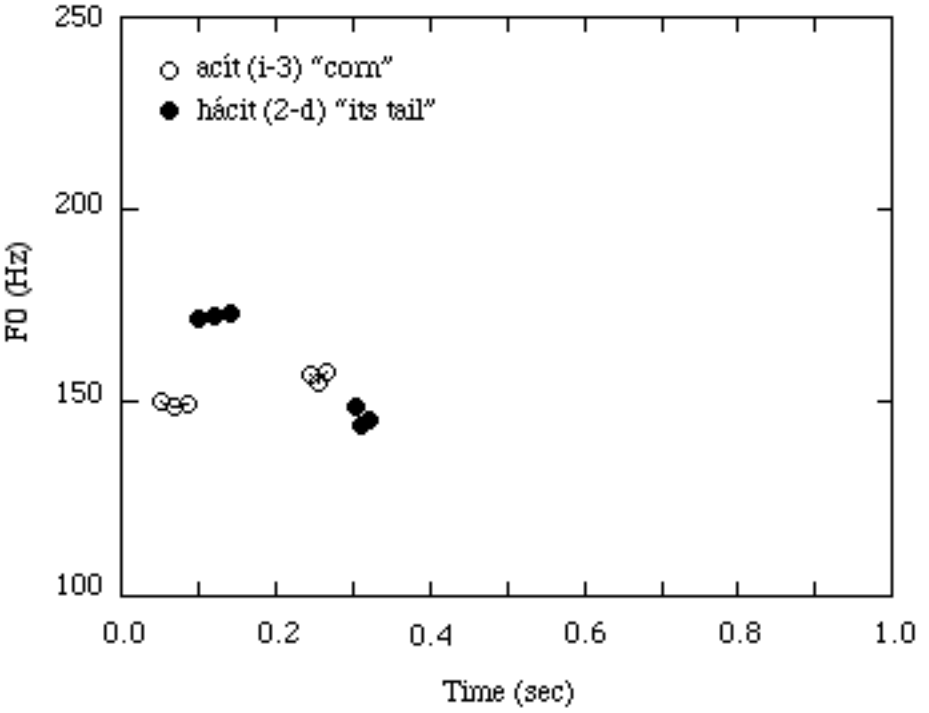
Martin & Johnson, Figure



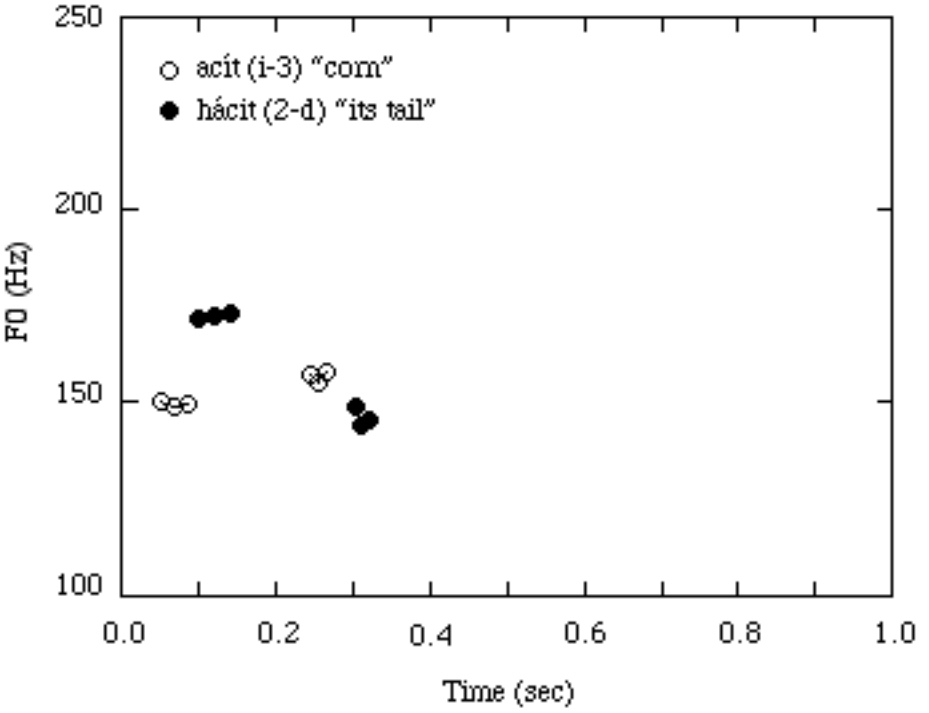
Martin & Johnson, Figure



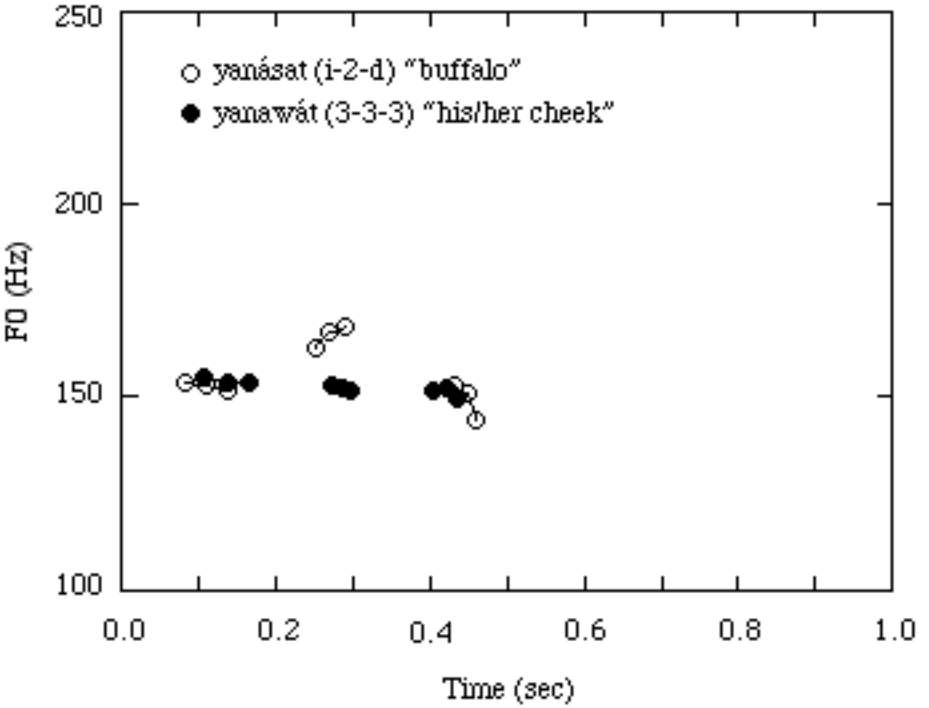
Martin & Johnson, Figure



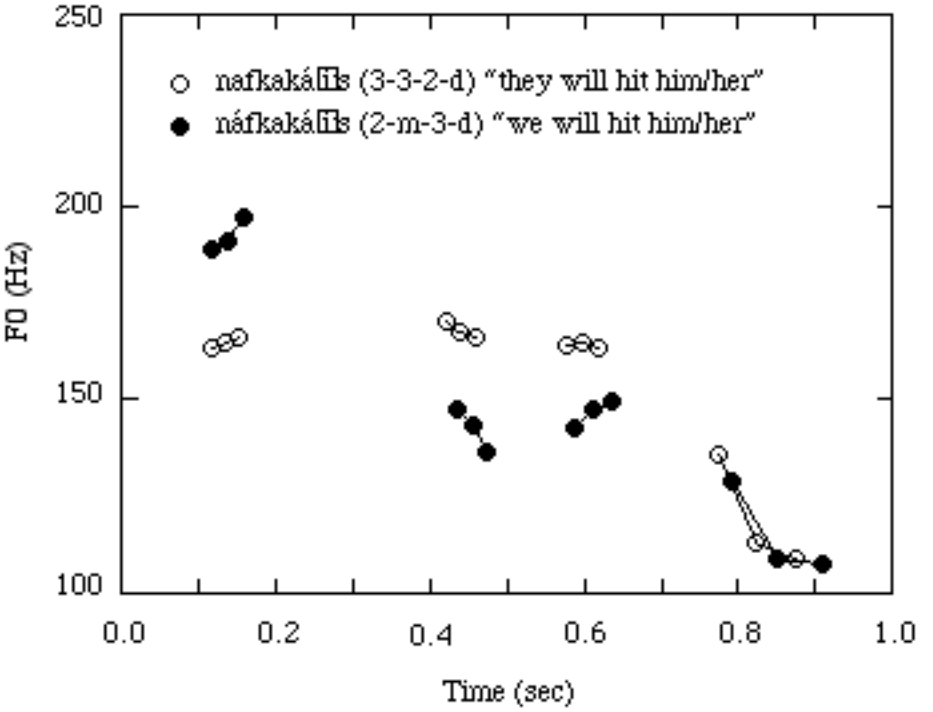
Martin & Johnson, Figure



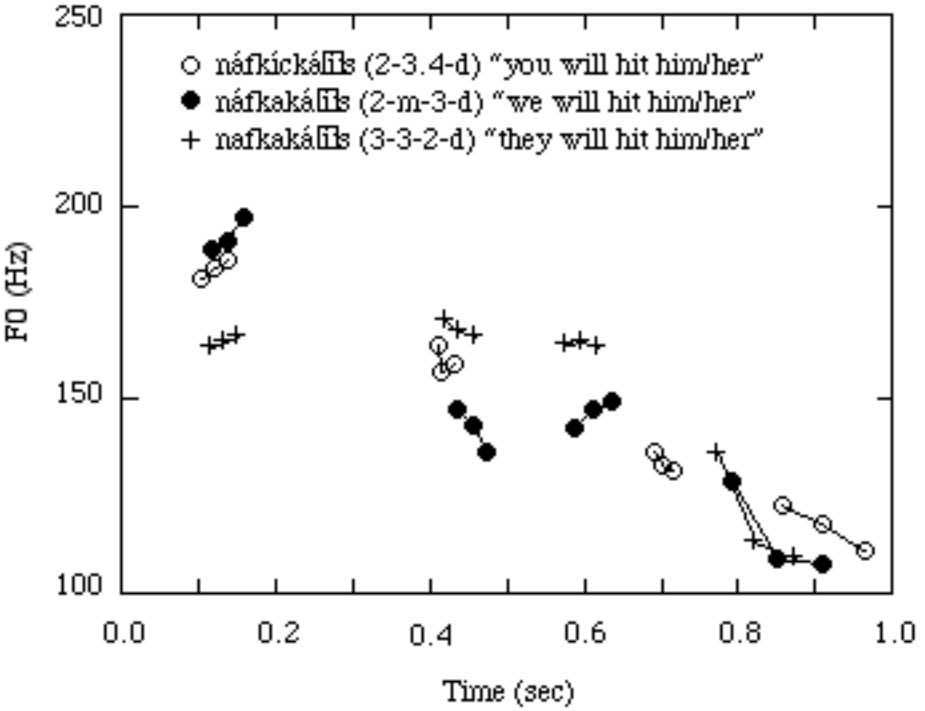
Martin & Johnson, Figure



Martin & Johnson, Figure



Martin & Johnson, Figure 1



Martin & Johnson, Figure 1