

# SUBGLOTTAL PRESSURE AND FINAL LOWERING IN ENGLISH

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## ABSTRACT

Quantitative models of intonation in a variety of languages typically specify a long-range downtrend across the sentence that provides a declining backdrop for the steeper rises and falls of more local pitch events such as accents and word tones. Several studies of this “declination” in English and several other languages have isolated a component of somewhat steeper decline that covers only the last few centiseconds of “lab speech” utterances. Other studies suggest that this “final lowering” may be particular to utterances with a “declarative intonation” pattern, and that it is associated particularly with the ends of discourse units. Thus final lowering seems to be associated pragmatically with a sense of fading off or finality. To see whether final lowering can be attributed in part to a fading off of subglottal pressure, we examined the two measures together in two databases of utterances that varied in intonation contour. To minimize confounds from more local pitch specifications, we looked at the relationship between final lowering and subglottal pressure only in the intonational “tail” — i.e., the portion of the contour after the last pitch accent. The slope of the decline of the subglottal pressure varied as a function of the phonological specification of the tones in the tail. Utterances with declarative intonation or with any other contour sharing the phonological specification of a low tone at the end of the tail consistently showed a decline in subglottal pressure, whereas utterances with “yes-no question intonation” or any other contour sharing the phonological specification of a final high tone showed lesser declines or even increases.

## 1. INTRODUCTION

In many languages, fundamental frequency (F0) declines over the course of an utterance. This downtrend has been attributed to the decline in subglottal pressure (Ps) that has been observed over the exhalatory phase in speech (e.g., [1]), but this attribution is controversial [2, 3]. Strik & Boves [4] have suggested that the discrepancy among earlier studies stems from not separating out different local and global components of F0 variation. Indeed, when variation in local F0 pattern for accents is separated from the variation in global F0 level observed when talkers vary overall loudness, variation in Ps level is more highly correlated with the latter [5].

Studies of long-range F0 trends that systematically vary discourse context or intonation contour as well as utterance length suggest that downtrend can be decomposed into several different parts, associated with different discourse functions. One component of the downtrend that has been identified in

this way is “final lowering”, a decline in backdrop pitch range for the last few centiseconds of declaratives [6, 7, 8], with more drastic decline indicating a stronger discourse disjuncture [9, 10]. Given its apparent connection to declarative intonations and the discourse function of indicating topic finality, it seems plausible to think of final lowering as a linguistically meaningful “fade-out” — i.e., a somewhat shorter-term version of the change in global F0 level that occurs when the talker manipulates overall loudness. Such a characterization predicts that final lowering will be associated with an utterance-final decline in Ps as well as in F0.

In this paper, therefore, we examine the relationship between Ps and final lowering in two corpora of American English sentences. The sentences exemplified many different intonations, including a canonical “declarative contour” (with a steep fall from the accented syllable), a “yes/no question contour” (in which F0 rises to a plateau immediately after the last accent and then rises again to a higher value at the end of the sentence), and an “uncertainty contour” (in which a scooped rise-fall accent is followed by a much smaller final F0 rise). To tease apart final lowering from local accentual effects, we looked at Ps variation only after the last pitch accent. In the intonational analysis we adopt [11, 12], the F0 pattern here is analyzed by a sequence of two phrase tones, either of which can be high (H) or low (L). The phrase accent accounts for F0 between the last pitch accent and the last centisecond or so of the utterance, and the following boundary tone accounts for the very end — e.g. LL, HH, and LH for the declarative, yes/no question, and uncertainty contours. There was a strong correspondence between boundary tone type and the slope of Ps decline over the portion of the F0 contour described by the transition from the phrase accent to the boundary tone. In contours with L boundary tones, the slope was always negative, whereas in contours with H boundary tones, the slope was positive on average regardless of the actual F0 value at the end.

## 2. METHODS

The data used in this study were originally recorded for other purposes. Corpus 1 is from an investigation of low tones in English intonation [13], whereas Corpus 2 is from an ongoing study of the interaction between spectral tilt and the physiological control of pitch. The speaker for both corpora is the second author, a female speaker of American English. Subglottal pressure was recorded from a catheter-type transducer inserted through the nose and pharynx to a position below the glottis. The Ps signal was digitally smoothed in order to remove the low-amplitude periodic component due to vocal fold

1. High rising tail in yes-no question contour:  
D'you have a lean mini-noodle dish?  
L\* L\* H- H%
2. Low rising tail in a contour indicating pragmatic uncertainty:  
We have a lean mini-noodle dish.  
H\* L\*+H L- H%
3. Falling tail in the canonical contrastive emphasis contour:  
We have a lean mini-noodle with beans.  
H\* L+H\* L- L%
4. Falling tail in a (2-phrase) canonical declarative contour:  
We have a lean mini-noodle dish.  
H\* L- H\* L- L%
5. Falling tail after a downstepped nuclear accent:  
We'll have the lean mini-noodle with beans.  
L\* H\* H+L\* H+L\* L- L%

**Figure 1:** Sentences and intonation contours for Corpus 1.

vibration. (See [13] for more detail concerning recording and processing.)

In the first corpus, there were five different intonation contours, listed in figure 1. (See [13] for a more complete description of the intended discourse contexts and meanings.) These utterances were produced at three self-selected levels of vocal effort (soft, normal, and loud voice), and there were about twenty tokens for each intonation at each vocal effort level.

In the second corpus, there were 8 different contours, produced on three different “sentences” — the three women’s names *Mary Anaheim*, *Marianna Heim*, and *Marie Annapolis*. Figure 2 lists the intonation patterns as they would be aligned to *Mary Anaheim*. The tail is the portion after the last pitch accent. For example, in the seventh (“contrastive”) intonation pattern, the tail covers the material after the L+H\* on the first syllable of *Anaheim*. The different stress patterns of the names provides for variation in the length of the tail. For example, when contour 2 is realized on *Marianna Heim*, the tail covers only the last part of the syllable *Heim*. Two pairs of contours also differ in stress pattern, to provide further variability in the length of the tail. In contour 7, the sentence stress is on the surname, whereas in contour 6 the sentence stress is on the given name, so that the tail after the L+H\* accent covers all of the utterance after the first syllable. There is a parallel contrast in the length of the rising tails between contours 1 and 2.

Each of the three phrases in each of the eight intonation patterns was produced at two self-selected levels of vocal effort (normal versus loud voice). There were about five tokens for each intonation pattern at each vocal effort level for each name.

Figure 3 shows sample signal traces for tokens of contour types 2, 3, 4, and 8 from corpus 2. For each utterance, the upper panel is the fundamental frequency and the lower panel is the subglottal pressure. In order to concentrate on the area of the sentence after the last pitch accent, we identified an “F0 peak” which was the lowest point in the F0 trace for final L\* accents and the highest point in all the others. The “F0 peak” is marked on each F0 trace in figure 3. The Ps in the portion of the sentence after the F0 peak was divided into two subregions on either side of an “elbow” that we took to correspond to the time when the phrase accent target was achieved in the F0 and the F0 began to follow a trajectory to the boundary tone target

### Rising tails

1. Yes-no question contour with early nucleus:  
Mary Anaheim.  
L\* H- H%
2. Yes-no question contour with late nucleus:  
Mary Anaheim.  
L\* L\* H- H%
3. The “uncertainty” contour  
(cf. corpus 1, type 2):  
Mary Anaheim.  
L\*+HL- H%

### Falling or level tails

4. The calling contour:  
Mary Anaheim.  
H\* H\* !H- L%
5. The surprise-redundancy contour:  
Mary Anaheim.  
L\* H\* L- L%
6. The canonical contrastive pattern with early nucleus:  
Mary Anaheim.  
L+H\* L- L%
7. Same as 6 with late nucleus:  
Mary Anaheim.  
L+H\* L- L%
8. The “flat hat” pattern:  
Mary Anaheim.  
H\* H\* L- L%

**Figure 2:** Intonation contours for the second corpus.

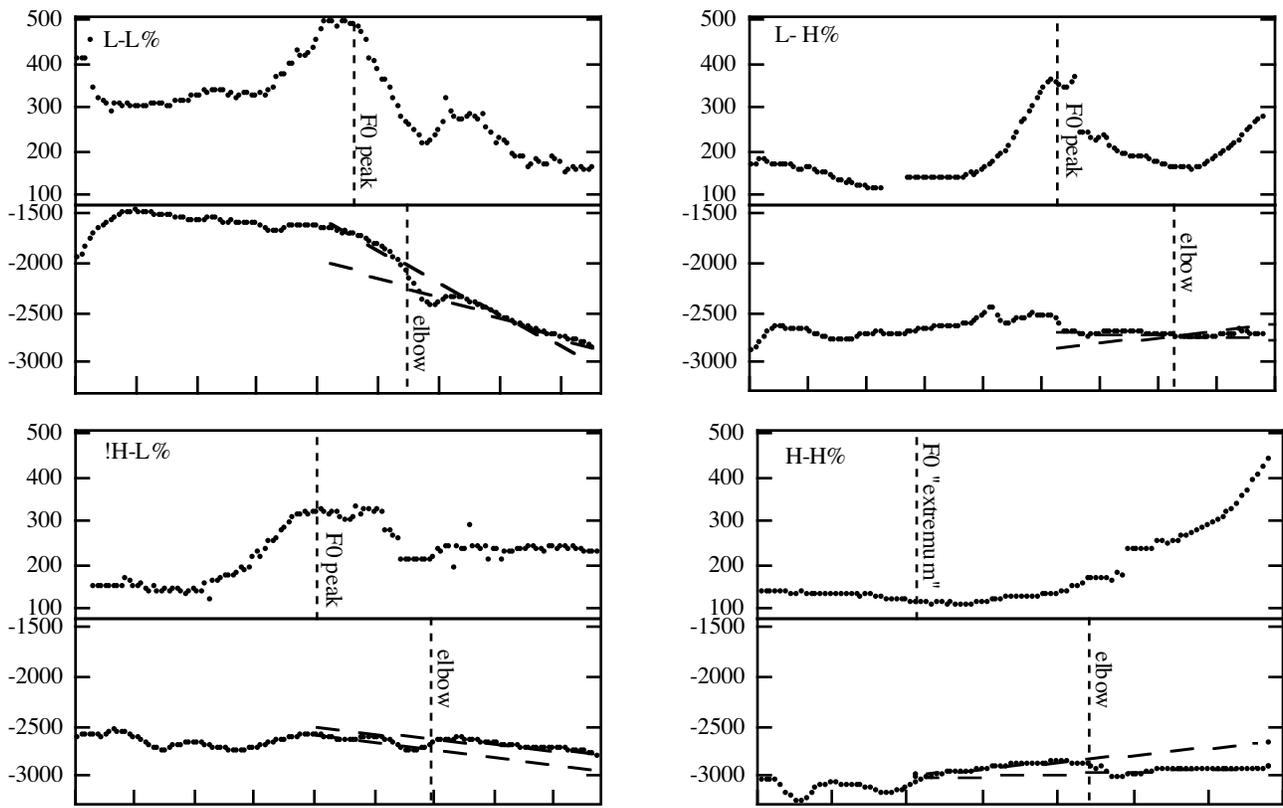
at the end of the sentence. This “elbow” in the Ps trace was defined by fitting the best pair of regression lines over two contiguous sub-regions between the F0 peak and the end of the sentence. The “elbow” was the boundary between these two subregions. In figure 3, the bottom panels show the subglottal pressure with the fitted regression lines and the elbow marked. The measure of interest for this study, then, was the slope of the regression line which describes the second subregion. The sign of this slope, whether negative or positive, indicates whether the Ps in the tail of the sentence is falling or rising. The mean value for the slope for each utterance type at each loudness level was then calculated, and the results are shown below.

## 3. RESULTS AND DISCUSSION

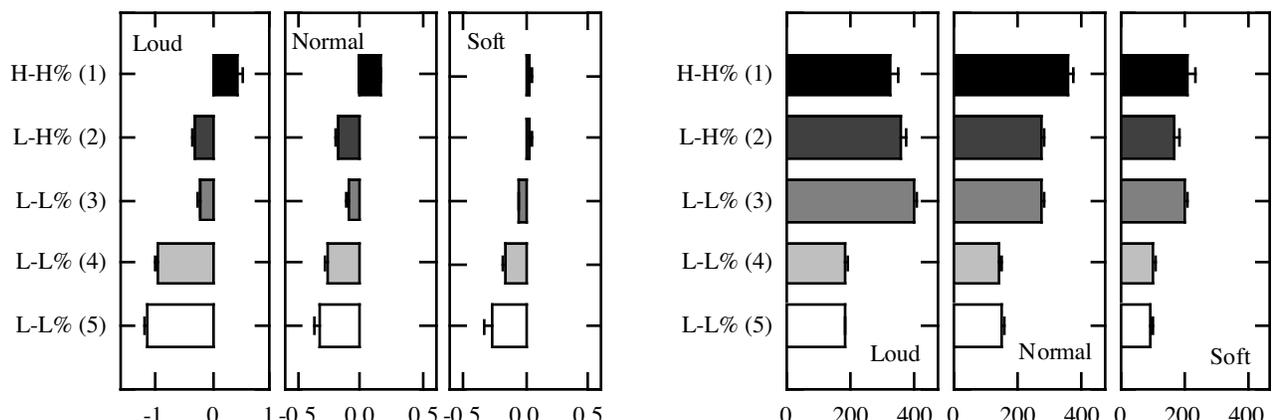
The left three panels in Figure 4 show, for the first corpus, the mean slopes of the fall-off of Ps in the part of the sentence described by the boundary tone. There is a separate panel for each loudness level. The right three panels in Figure 4 show the mean F0 values at the end of the sentence, measured at the point where phonation ends. In the Loud and Normal conditions, the only sentence type which has a positive slope for Ps in the part of the sentence described by the boundary tone is the yes/no question. All other types of sentences have a negative slope. In the Soft condition, both yes/no questions and uncertainty contours (the two contours with H boundary tones) have a positive slope for Ps in the part of the sentence described by the boundary tone. All of the other types (all of which have L boundary tones), show a negative slope for Ps in the tail of the sentence, after the phrase accent.

The left two panels in Figure 5 show the analogous means for the second corpus, averaged over all three phrases for each type. In the Loud condition, the slope of the Ps in the part of the sentence after the phrase accent is positive for the yes/no question with a late nucleus (where the rising F0 tail is quite long). It is quite slightly negative for the uncertainty contour and for the yes/no question with an early nucleus (both of which also have a H boundary tone). For all the other types of intonations in this corpus (all of which have a L boundary tone), the slope of the Ps in the part of the sentence described

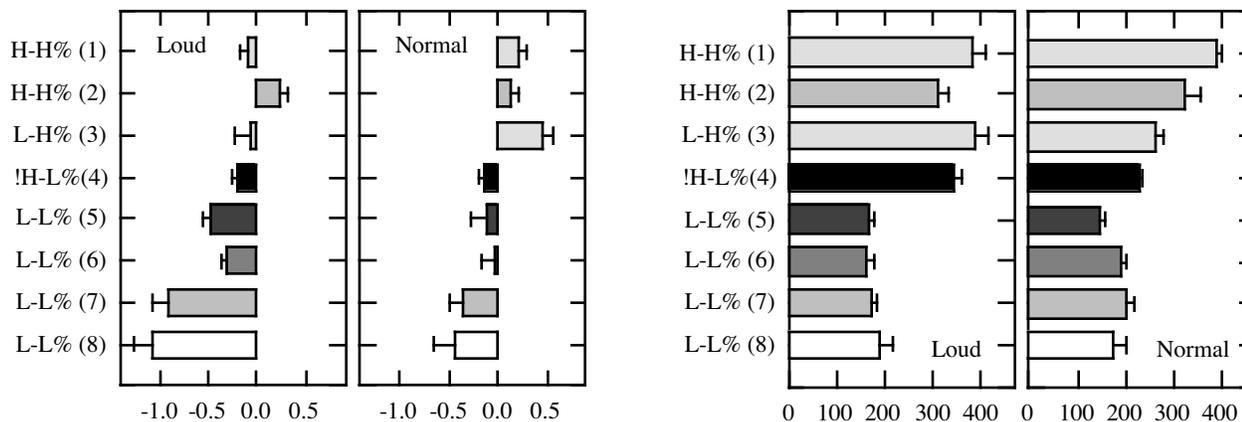
by the boundary tone is negative, even when the F0 value at the end of the sentence is as high as it is when there is a H boundary tone, such as in the calling contour (!H-L%). In the Normal condition, the Ps slope is positive for all three types of sentences with H boundary tones— namely, for yes/no questions with an early nucleus, for yes/no questions with a late nucleus, and for uncertainty contours. All of the other types of sentences (the ones which have a L boundary tone), also have a negative slope in Ps, again, even when the F0 value at the end of the sentence is quite high, such as with the calling contour.



**Figure 3:** Sample tokens of utterance types 2, 3, 4, and 8 from corpus 2 with the landmarks labeled and regression curves fitted to the Ps traces. The top panel in each case is the F0 and the bottom panel is the Ps.



**Figure 4:** Mean Ps slopes (left) and mean F0 values at the end of the sentence (right) for corpus 1. Error bars show standard error.



**Figure 5:** Mean Ps slopes (left) and mean F0 values at the end of the sentence (right) for corpus 2. Error bars show standard error.

## CONCLUSION

This study examined subglottal pressure as an articulatory correlate of final lowering. It showed a steeper decline in Ps for intonation contours ending in a L boundary tone, regardless of the F0 level that realized that tone. Pierrehumbert and Hirschberg [12] describe the meaning of the H boundary tone as indicating that the current intonational phrase should be interpreted with respect to material that will follow in the discourse. The L boundary, by contrast, indicates that the current phrase ends an interpretative unit — that is, it cues finality or disengagement from the topic at some level of the discourse hierarchy. Our results thus suggest that final lowering is not just a manipulation of intended pitch, but also of intended volume. This supports an account of final lowering as a shorter-term analog of the relationship between overall vocal effort and global F0 level. Increased global pitch range as a consequence of greater vocal effort has been associated with greater speaker “involvement” [14] or an “aroused” emotional state [15]. The reduced pitch range associated with lesser vocal effort, then, signals lesser speaker involvement or emotional disengagement. Previous studies have documented the manipulation of global pitch range as a linguistic device to differentiate such meanings as the “incredulity” versus the “uncertainty” interpretation of contour type 2 of our first corpus [16] and incredulous rhetorical versus unmarked yes-no question interpretations of sentence final rising configurations [8, 17]. Our results suggest that final lowering is a shorter term use of this same device.

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