

# Prosodic Boundary Patterns in Hebrew: A Case Study of Continuous Intonation Units in Weather Forecast

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## Abstract

In this study, we examine acoustic features around boundaries of Intonation Units that have been perceptually segmented. An account of both sides of a boundary is the concept of analysis, i.e. acoustic features are measured at the end of one IU and at the beginning of the following IU. Since Hebrew is our target language, an account of the stress assignment on the prosodic word level was taken. Results show that duration and pitch characteristics at continuous boundaries are affected by the stress metrical structure.

## 1. Introduction

In this case study, we examine the prosody of Intonation Units (hence, IU) boundaries of TV weather forecast broadcasts. Speech during the weather report is traditionally fast. The goal of the speaker is to convey the maximum amount of information in a minimum amount of time and in the most comprehensible way possible. Indeed, one can hypothesize that the broadcaster would use a lot of prosodic cues to accentuate the syntax. The theoretical approach in this study is that the intonative structure is prior in perception to the syntactic one [4]. In the present case study of planned speech with consolidated patterns and the specific context of weather forecasts, we presume a full alignment between IUs and syntactic structures. For this type of corpus, a prosodic terminal boundary that reflects “nothing more to say” is expected at the end of each broadcast, and the rest of the IUs are expected to have a continuous prosodic boundary that reflects “more to come”, which means that the continuation has a “discourse value” as it links together different chunks of text that could otherwise function as separated utterances (clause chaining) [9].

By adopting the notion of prosody as the main cue for speech units' segmentation, the working hypothesis for this research is that the IU encapsulates the basic structural unit of spoken language analysis [3]. Thus, we choose the way spoken language is broken down into ‘phrases’ and the nature of boundaries between them as the main element of analysis [10]. This is, of course, a phonetic view of tone group boundaries. “In phonology, boundaries are abstract entities which are the logical consequence of assuming that intonation has a structure, and are not necessarily phonetic events. Phonetic breaks occur where the underlying structure allows it” [5]. By characterizing the prosodic boundaries in this kind of speech, we suggest a focus on the relationships between adjacent IUs as a concept of analysis that will enable us to examine their segmental content, and to extend the concepts from this corpus to other varieties of spoken language, e.g. spontaneous speech.

## 2. Research questions

Three questions were asked: first, if there is any lengthening characteristic at the end of an IU, which syllable/s carry/ies this characteristic? This question is derived from the regular stress assignment and metrical structure of Spoken Hebrew which has final stress pattern. This means that in both nouns and verbs, the most common pattern of stress assignment is final [1]. We therefore expect to find final lengthening at the end of an IU to be in full alignment with the stressed syllable of the lexical word. The second question is about the pitch characteristic: what final tone characterizes the continuous IUs and what happens as a consequence in the following IU. The literature characterizes the default final tone of continuous IUs as a rising tone [9] while the following IU is supposed to begin at mid-pitch range since the speaker tends to reset his speech into his default pitch range. Therefore, a downward trend of pitch is expected at the boundaries. The last question refers to the dominant prosodic patterns of continuous IUs. Prosodic patterns will be analyzed as a composition of the duration results on both sides of the boundary, i.e. the ratio between the penultimate, ultimate and the first following syllables, and the intonation and pause features.

## 3. Methodology

The aim of this study is to observe a type of speech that has its own specificities, but probably has many similarities with spontaneous speech, discourse and reading speech. It is interesting to see how it is related to results in the literature dealing with other kind of corpora. Finding a model of prosody for this type of corpus can have many applications in itself, including applications related to text-to-speech or inversely speech-to-text. TV weather forecast broadcasting was chosen because of three factors: first, it is *planned* speech where a skilled reader reads out a previously constructed text; second, weather forecast broadcasting is a *daily event* on TV and radio and therefore it is easy to compile from it, to correct it, modify it or extend it to a larger corpus, and eventually to consider separately one or many speakers, genders or languages in that type of corpus; third, we assume native speakers *recognize* such speech in their languages as weather forecast broadcasting while hearing it, without too much attention to the segmental content (e.g. words, syntax). This means that this kind of discourse has its own prosodic style.

Recordings of weather forecasts were retrieved from the Internet, from Israel Channel 1 <<http://tahazit.iba.org.il/>>. A corpus of seven days of broadcasts was compiled during March - 6/7/10/12/13/14/18, 2007. The total length of records is 7.28 minutes (37.394<sub>sec.</sub>; 53.656<sub>sec.</sub>; 64.117<sub>sec.</sub>; 97.442<sub>sec.</sub>;

53.719<sub>sec.</sub>; 63.783<sub>sec.</sub>; 67.153<sub>sec.</sub> respectively). All were female broadcasters.

The perceptual segmentation into IUs was done by the native Hebrew speaker author. Although such a method calls for subjectivity, it was proved to be reliable enough in [7]. Each IU boundary was marked perceptually as either continuous, whenever the final tone of the IU signaled “more to come” or as terminal, when intonation signaled “nothing more to say.”

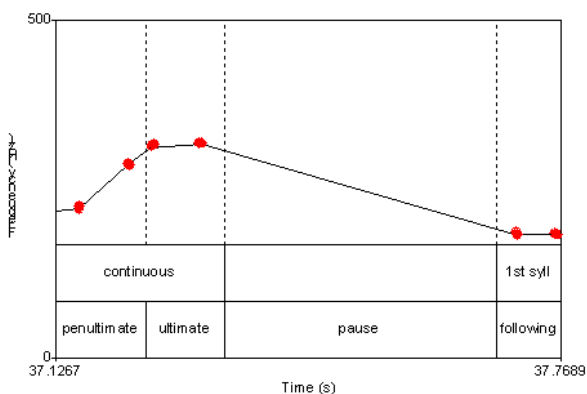
### 3.1.1. Durational tagging

For the study of intonation and duration (or more specifically, rhythm) around the boundaries, one needs to choose and define a unit of segmentation adequate for this. The basic prosodic duration unit in Hebrew is the syllable. According to the lexical prosodic typology [2], Hebrew is considered to be an accent language, and two possible patterns of syllables are found: stressed (*S*) and unstressed (*u*). In Hebrew, the most common pattern is a final stressed syllable. Nonetheless, variations in syllable duration are considered as allophonic although stress patterns are phonemic, meaning that Hebrew vowels are quantity-insensitive. In order to see what the ratio between syllable length at the boundaries is, three syllables were measured: two syllables - penultimate and ultimate, at the end of an IU, and the first syllable at the beginning of the following IU (cf. Figure 1). Phonetically, it was found that in spoken Hebrew the last syllable in an IU (not specified *S* or *u*) is almost twice (1.99) the length than the first syllable in the following IU [8].

### 3.1.2. Pitch tagging

By using the PRAAT textgrid tool, Prosogram pitch contour stylization was carried out [6]. The nucl.textgrid was then manually adopted according to the following parameters: the last couple of voiced segments, nuclei, of an IU were stylized by four pitch points (at most of the boundaries they were divided by the two S-u syllables); the first nuclei of the following IU was stylized by two pitch points; the gap in between, if any exists, reflects a pause (cf. Figure 1).

Figure 1: Schematic tagging at the boundaries.



## 4. Results

Among 221 IU boundaries, 200 (90.5%) were perceived as continuous, “more to come” boundaries, and 21 (9.5%) were

perceived as terminal, “nothing more to say” boundaries (of which 7 were indeed the last IUs in each broadcast). This makes continuous boundaries an inevitable research target. The fact that none is a truncated boundary reflects the planned characteristic of this type of speech: a TV weather broadcast, which does not tolerate errors of production. The following results refer only to the 90.5% of the continuous boundaries.

### 4.1. Pause parameter

Pauses were tracked manually. All pauses are breath pauses and were present in 56% of the continuous boundaries. All pauses are above 100ms. The longest pause duration is 680ms and the average pause length is 350ms. During four days, pauses were present in around 50% (46-53%) of the boundaries, while during three other days, pauses were present in over than 66% (66, 75 and 87! %). We tend to refer this difference to the broadcaster’s idiolect, since the chief weather broadcaster of Israel Channel 1 is the speaker during all 4 days with around 50% pauses. During the other days, two other broadcasters spoke, and results show that they spoke with many more pauses, as mentioned above.

### 4.2. Rhythm parameter

The rhythm parameter assumes both lengthening at the end of an IU and an anacrusis, compression of syllables, at the beginning of the following IU. The notion of rhythm was chosen for its comparative aspect. From the data in Table 1, it is evident that the average *S* syllable is twice in length than the adjacent (following or preceding) *u* syllable and also from the first syllable in the following IU, *F*.

Table 1: Duration (seconds) of the three syllables in the boundary: (*S*)stressed, (*u*)nstressed, (*F*)ollowing.

Duration	Last <i>u</i>	Last <i>S</i>	Following
Average	0.13	0.22	0.12
Min	0.03	0.06	0.03
Max	0.33	0.64	0.32

Following our first research question, an account of the stress pattern at the lexical word level was taken. An average of 78% (68-86% range among recordings) words at the end of the IU are stressed final words, and 22% (14-32% range among recordings) are penultimate words (stress is at the prefinal syllable). Common penultimate lexemes/morphemes in weather forecast broadcasts boundaries are: IPL nominal suffixes (e.g. *o.* "ta.nu<sup>1</sup>=‘us’, *Ra.* "i.nu=‘we saw’, "la.nu=‘for us’), FSG participles (e.g. *jo.* "Re.det=‘falling down’, *no.* "se.fet=‘additional’); loan words (e.g. *tem.pe.Ra.* "tu.rot=‘temperatures’), parts of the day (e.g. "laj.la=‘night’), "e.Rev=‘evening’, *tso.ho.* "Ra.jim=‘noon’, "bo.keR=‘morning’); places (e.g. *je.Ru.Sa.* "la.jim=Jerusalem, "ne.gev=Negev, desert region, *e.* "Ro.pa=Europe, *ha* "a.Rets=‘the country’), weather words (e.g. "o.veX=‘haze’, "Se.leg=‘snow’, "Xo.Ref=‘winter’). One antepenultimate loan word, "mak.si.mum=‘maximum’, was tracked at the boundaries.

In addition to the known Hebrew tendency toward stress final words that is reflected in our corpus, we wanted to examine the ratios of the mentioned three syllables (*S*, *u* and *F*) in the two stress groups. In order to see the correlation between stress assignment and the lengthening characteristic, an independent samples T-Test was done in the two groups –

<sup>1</sup> SAMPA notation is used throughout this paper.

the stress final and the penultimate stress – for two variables: the ratio of *S/F* syllables and the ratio of *u/F* syllables. Significance was found in the *S/F* ratio ( $t=-4.037$ ,  $p<0.05$ ). The *u/F* ratio showed no significance. In a paired samples T-test for the two variables, the *S/F* ratio and the *u/F* ratio, a significant positive correlation was found in both stress groups (final stress group 0.836, penultimate stress group 0.673,  $p<0.05$ ), i.e. the higher the *S/F* ratio, the higher the *u/F* ratio; but in the penultimate stress group the difference between ratio means (*S/F* and *u/F*) was not found significant ( $t=-0.71$ ), and in the final stressed group, the difference between the two means was found significant ( $t=12.9$ ,  $p<0.05$ ). These findings suggest that in stress final words, lengthening indeed aligns with the stressed syllable and rhythm parameter can be set whenever the *S/F* ratio is  $>2$ . On the other hand, among penultimate stress words, the two largest groups are of 11 words with both ratios larger than 2 (*S/F* and *u/F*  $>2$ ), and of 13 words with both ratios larger than 1. Since statistical results show that the two ratios do correlate with each other, we hypothesize that in penultimate stress words, the lengthening characteristic does not align with the penultimate stressed syllable, but with the final unstressed syllable of an IU. Since our corpus showed a very small amount of 48 penultimate stress words at final IU position, this is left for future research. To conclude, the rhythm parameter was set according to the stress final results, whenever the *S/F* ratio was  $>2$ , which was found in 49% of the continuous boundaries.

### 4.3. Pitch parameter

As shown in Figure 1, there were six pitch values to examine for each boundary: the first and last points of the pitch stylization were used for each voiced part of each syllable. In this way, two pitch values for the penultimate syllable, two for the ultimate and two for the following were obtained.

Table 2: *Pitch values (Hertz) at the 7 days: start, end, maximum, minimum, mean and standard deviation.*

Date	P start	P end	P max	P min	P mean	P std
6.3.07	281	166	360.69	98.26	241.35	47.35
7.3.07	208	161	443.10	75.20	226.97	50.45
10.3.07	240	-	442.22	69.14	228.91	53.06
12.3.07	190	117	435.93	117.11	198.23	30.33
13.3.07	234	156	380.02	71.11	225.14	47.04
14.3.07	283	147	417.64	68.01	237.33	61.84
18.3.07	190	151	416.21	82.71	231.30	65.10

#### 4.3.1. Pitch boundary contour

The pitch excursion upward or downward was set between the penultimate and the ultimate syllables in an IU (third pitch value minus second pitch value; cf. Figure 1) and between the last and the first syllable in the following IU (fifth pitch value minus fourth pitch value; cf. Figure 1). “Stable” pitch slope was annotated in 5% of the cases.

The trends that reflect the transition between the last two nuclei (alternating unstressed-Stressed syllables) are the following: 74% upward, and 19% have a downward trend (7% stable). This meets our expectations about the rising tone at the end of continuous IUs, and since lexical stress is manifested by pitch, in addition to energy and duration, in the case of final stress words, the rising pitch can be attributed to the shift from

the *u* to the *S* syllable. But in penultimate words, it was surprising to find 69% with an upwards trend and only 8% with a downward trend between the last two syllables at the end of IUs. These results can suggest either that in Hebrew the prosody at the ends of IU “overwrites” the stress pattern, or that the pitch accent pattern at boundaries also exists independently of the stress assignment at the word level in Hebrew. Since our corpus only provides us with a quite limited number of penultimate words, this has to be studied more deeply in future research.

The trends that reflect boundaries between IUs are the following: mostly downward (75%), and 23% direct upward (3% stable). 70% of the following IUs start between 180-300Hz, which according to the figures in Table 2, can be considered as mid-high pitch range.

By grouping the pitch excursions (upward-downward combinations) of the third and fifth pitch points to each boundary, we get nine possible pitch boundary contours (cf. Figure 2): The most frequent (66%, circled pattern at Figure 2) is the Up-Down contour, i.e. upward at the end of IU and a downward transition to the onset of the following IU. (cf. Figure 1 for illustration). The UP-UP contour (left most pattern in Figure 2) is at 11.5% of the boundaries and all the other possibilities (e.g. Down-Up, Stable-Down) are less than 8% each.

Interestingly, the maximum (absolute) values of the pitch gaps are systematic with the preceding results as the following: in six of the 7 days, the maximum upwards trends (e.g. 232Hz gap/slope) are between the penultimate and the ultimate syllables, i.e. between the *u-S* syllables of final stress words (in a single day, it is between the *S-u* syllables of penultimate stress words).

In all 7 days, the maximum downward trends (e.g. a gap/slope of -221Hz) is at the boundary, i.e. between IUs. Since the dominant pattern of pitch tendency is the Upward-Downward one, these results demonstrate the speaker’s effort at the continuous boundary: maximum efforts upward at the last syllable of an IU, and ensuing maximum slope downward into the following IU.

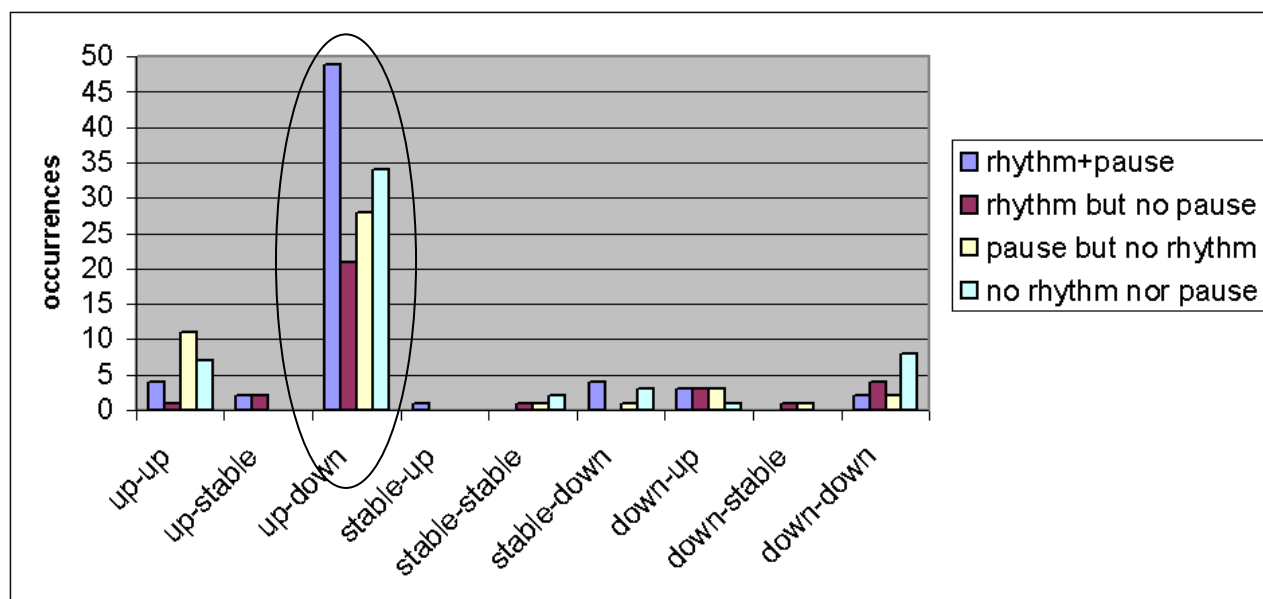
#### 4.3.2. Patterns of prosodic boundaries

All continuous boundaries were then analyzed statistically to see if there is any correlation between the three parameters that were described above: pauses, rhythm, and pitch boundary contour. Pearson Chi-square test shows a significant correlation between the rhythm and the pause parameters ( $\chi^2=7.42$ ,  $p<0.05$ ). The largest group of boundaries has both rhythm and pause characteristics (32.5%), the next group of boundaries has neither rhythm nor pauses (27.5%), then pauses with no rhythm characteristics (23.5%) and the smallest group is of rhythm but no pauses (16.5%). Figure 2 demonstrates the correlation between the three parameters. Although with no significance, but worth noting is the fact that the pattern Upward-Downward+pause+rhythm (the tallest dark column at the circled pattern, cf. figure 2) was found most frequently.

## 5. Discussion

In this case study, we have tried to plot continuous boundary patterns in TV weather forecast broadcasts in Hebrew. Although rhythm, pitch and pauses are the most

Figure 2: Patterns of prosodic boundaries. Analysis of three parameters on both sides of the boundary: pause, rhythm and pitch contour.



common parameters in prosodic literature, and IU literature in particular, a case study on Hebrew spoken discourse sheds light on language specific characteristics as the relationships between lexical stress and IU pattern.

In regards to the three research questions, as usually mentioned in the literature for other languages, the syllable that carries the lengthening characteristic at the end of an IU is generally the final syllable. In case of final stress words, the lengthening is in full alignment with the lexical stress. This is not the case in IUs that end with penultimate stress words. We suggest that the lengthening characteristic does not align with the penultimate stressed syllable but with the last unstressed syllable or might spread over the last two syllables, but this remains open to future study. As to the pitch contour of continuous IUs in weather forecasts, this was found to be a continuous rise at the end of IUs that is followed by a reset downward, back into the mid-high pitch range of the speaker. This meets our expectations about the rising tone at the end of continuous IUs, and in case of final stress words, the rising pitch can be attributed to the shift from the unstressed to the stressed syllable. In penultimate stress words, the results can suggest either that in Hebrew the prosody at the ends of IU "overwrites" the stress pattern, or that the pitch accent pattern at boundaries also exists independently of the stress assignment at the word level in Hebrew. Since our corpus does not provide us with enough penultimate words, this has to be confirmed in future research by using a corpus that will include a larger amount of penultimate words.

## 6. Acknowledgments

We would like to thank Prof. Shlomo Izre'el for his comments and suggestions, and to the reviewer for suggesting the recent publication of Turk & Shattuck-Hufnagel (2007) that presents related results about the duration of segments for American-English.

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