Project 4: Vlach Stress

Introduction

For this project, I will look at measurements of pitch, intensity, duration and vowel quality to analyze stress in Meglan Vlach, which I hypothesize is similar to English stress. Thus, I expect to find that pitch, intensity, and duration of a syllable is increased when the syllable is stressed, and reduced when the syllable is not stressed. It is also likely that vowel quality will be reduced (towards a mid-central vowel) in the unstressed syllables. By measuring the values mentioned above, I hope to confirm that pitch, intensity, duration, and vowel quality are indeed factors in stress in Vlach, and furthermore I hope to quantify these effects to some extent.

Methods

Similar to past experiments, the native speaker produced words from a randomized wordlist, which consisted of six instances of each of the following four words:

[∪ιντρΑ] he enters
[ιν∪τρΑ] he entered
[∪ναλτυ] tall (m. adj.)
[ναλ∪τυ] he grew

As can be seen, these four disyllabic words constitute two minimal pairs which differ only in the placement of stress. (Such minimal pairs occur often due to the conjugation of Vlach verbs, which results in pairs such as [∪ιντρΑ] / [ιν∪τρΑ], distinguishing present from past tense.) The full wordlist, and the frame sentence in which the words were pronounced, are included in the appendix. To help avoid confusion (due to the similarity of the words in the list), the stressed syllable was underlined and the English gloss was printed alongside each Vlach word. Also, I used a masking guide so that the speaker only saw one line from the wordlist at a time, limiting the distraction of other words in the list.

The words were recorded using a solid-state digital recorder (Marantz PMD660) and a non-condenser microphone in a soundproof recording studio. All recordings were made directly to wave files on a Compact Flash memory card, and then analyzed with the Praat software. A Praat script (included in the appendix) was used to gather the various measurements, as described below.

All files were annotated to denote the start and end of each syllable as well as the start and end of the vowel portion of the syllable. The full syllable was used to measure syllable duration, while the vowel portion was used to measure intensity, pitch, and formant frequency. This was necessary to eliminate any artificial reduction in intensity or pitch due the non-sonorant portions of the syllable (e.g. stop closures). Values for pitch, intensity, and formant frequency were all extracted using Praat built-in functions. See the script for more details.

The built-in functions in Praat were effective for extracting most measurements, but the data needed a minor amount of hand-correction after execution of the script. This included manually gathering some pitch measurements which could not be measured automatically by Praat (perhaps due to the low pitch level in the second syllable), and correcting for some halving in the pitch measurements (several unstressed second-syllable measurements were recorded at roughly 40Hz when they clearly should have been at 80Hz).

Results

The sections below summarize the results obtained for the four features hypothesized to be related to stress: duration, intensity, pitch, and formant frequency.

Duration

There was a visible trend relating stress to syllable duration lengthening. The data for the four syllables are summarized in the table below:

	[ιντρΑ]		[ναλτυ]	
	[ιν]	[τρΑ]	[νΑλ]	[τυ]
Unstressed Duration	196 (47)	262 (31)	262 (17)	221 (19)
Stressed Duration	214 (13)	295 (36)	354 (37)	299 (19)
Percent Increase	8.9%	12.6%	34.9%	35.7%

Table 1: Effects of stress on syllable duration. Times given in ms (standard deviation in parentheses).

The data clearly show that stressed syllables are roughly 10-30% longer than their unstressed counterparts. Interestingly, the magnitude of the lengthening effect varies between word-pairs: the [ναλτυ] pairs show a 35% lengthening effect for both syllables, while the [IντρΑ] pairs show a roughly 10% effect, which is slightly more pronounced for the second syllable than for the first.

Intensity

Intensity measurements also showed a positive correlation to stress. The data are summarized in the table below:

	[ιντρΑ]		[ναλτυ]	
	[ιν]	[τρΑ]	[νΑλ]	[τυ]
Unstressed Intensity	65.0 (1.4)	61.1 (4.3)	68.9 (1.6)	62.1 (4.7)
Stressed Intensity	71.3 (2.5)	71.0 (3.2)	75.7 (3.8)	69.4 (2.0)
Percent Increase	9.7%	16.2%	9.9%	11.8%

Table 2: Effects of stress on intensity. Intensity values in dB (standard deviations in parantheses).

These measurements show that stressed syllables have a significant increase in amplitude compared to unstressed syllables. For all cases, the increase in dB was around 10%; the word-final syllables [τρΑ] and [τυ] showed a somewhat more significant level of amplification (16% and 12%) compared to the word-initial syllables (both 10%). This may be related to the fact that word-final syllables naturally have an overall lower amplitude than word-initial syllables, and stressing the final syllable compensates for this effect as well as raising the intensity of the syllable.

Pitch

The table below summarizes the results for peak pitch. Mean pitch was also measured, but these values closely resemble the peak values and do not offer additional insight.

	[ιντρΑ]		[ναλτυ]	
	[ιν]	[τρΑ]	[νΑλ]	[τυ]
Unstressed Pitch	99.4 (2.4)	85.8 (4.6)	93.0 (3.2)	83.2 (4.4)
Stressed Pitch	118.8 (3.0)	118.6 (4.1)	110.6 (9.2)	121.3 (5.5)
Percent Increase	19.5%	38.2%	18.9%	45.8%

Table 3: Effects of stress on pitch. Intensity values in dB (standard deviations in parantheses).

Clearly, pitch is a significant factor in marking stress, with marked increases for all stressed syllables. The effect is more pronounced on the second syllable (38% and 46% increases) than on the first syllable (19% and 20% increases). This effect can be attributed to the significantly lower pitch of unstressed second syllables compared to unstressed first syllables (note that first and second syllable pitch is roughly comparable in the stressed cases). Thus a possible explanation may be that the speaker naturally has a decrease in pitch throughout the production of the word, but this natural effect is countered when the second syllable is stressed, in a similar manner as was seen in the intensity values.

Vowel Formants

The four tables below illustrate the effects of stress on the values of the formant frequencies in the four syllables. The trend is to reduce the vowel quality towards a more centralized sound in unstressed syllables; thus the frequency will either increase or decrease depending on the quality of the vowel (a high vowel will be lowered, whereas a low vowel will be raised). This is reflected in the positive and negative values for percent change in the tables below:

	[ιν]	
	F1	F2
Stressed	322 (5.7)	2363 (69.5)
Unstressed	306 (24.6)	2292 (49.2)
Percent Change	-5.2%	-3.1%

	[τρΑ]	
	F1	F2
Stressed	599 (26.1)	1281 (69.4)
Unstressed	521 (66.1)	1413 (38.7)
Percent Change	-13.0%	+10.3%

	[νΑλ]	
	F1	F2
Stressed	553 (57.0)	1357 (48.0)
Unstressed	437 (22.4)	1391 (23.9)
Percent Change	-21.0%	+2.5%

	[τυ]	
	F1	F2

Stressed	326	(22.0)	877	(44.4)
Unstressed	376	(30.5)	1051	(93.2)
Percent Change	+15.3%		+19.8%	

Tables 4-7: Changes in formant frequency for vowels in stressed and unstressed position. Frequencies in Hz (standard deviations in parentheses).

The tables above show that each vowel has a slightly different quality when produced in stressed versus unstressed positions. The vowel [ι] is the most constant, changing its formant frequencies by only a few percent. The vowel [u] in the [τυ] syllable shows the most regular and noticeable change, and the vowel [A] in the syllables [νAλ] and [τρA] also shows a significant difference between stressed and unstressed realizations. While the tables above show the quantity of the changes in terms of percentages, the figure below helps illustrate the quality of these changes, which all have the effect of minimizing the vowel quality:

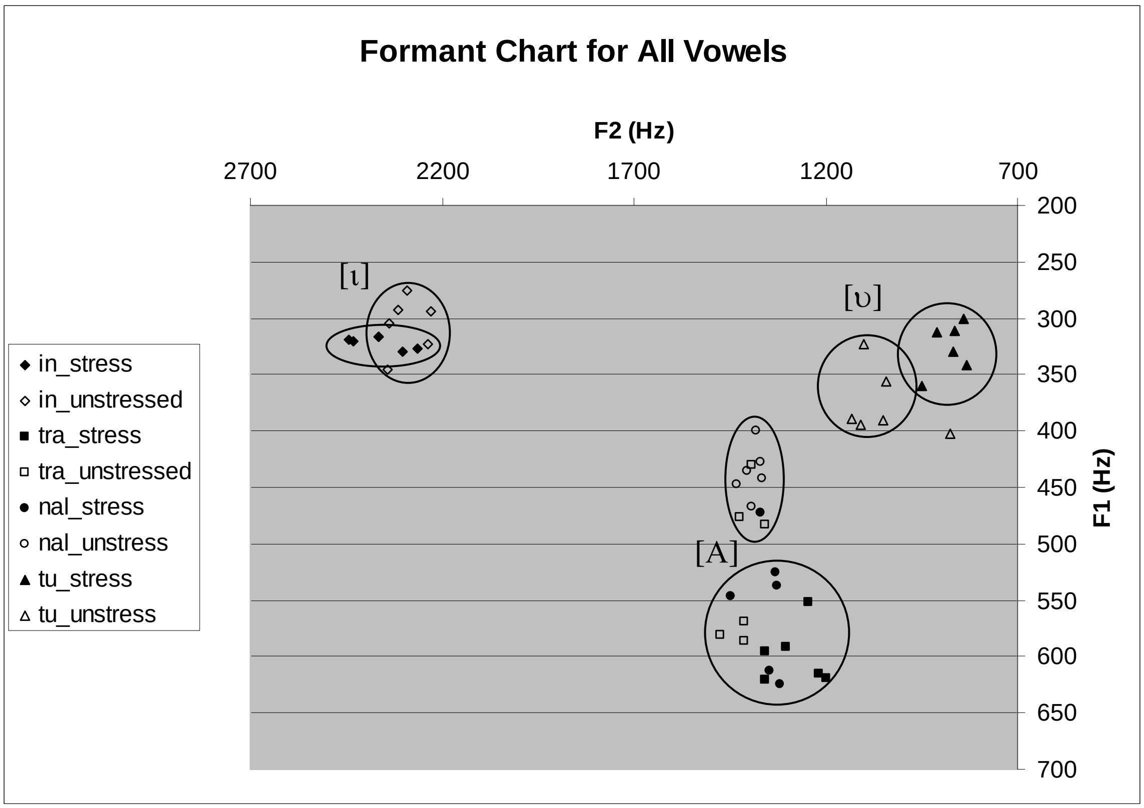

Fig 1: Formant chart showing stressed and unstressed vowels.

In the figure above, all instances of the recorded vowels are plotted, and these instances are grouped together with ellipses to illustrate the centralizing effect. The effect is seen most clearly on the [υ] vowel in the [∪ναλτυ] / [ναλ∪τυ] pair: the stressed, tense realization forms a distinct group than the lax, unstressed, and centralized realization (with one outlying instance).

The [i] vowels have a less clear distinction between stressed and unstressed realizations: while the unstressed instances tend to be less front than the stressed instances, there is a high degree of overlap between the two groups.

Finally, the [A] vowels show an apparent distinction between stressed and unstressed realizations, but there is a certain amount of inconsistency in their production. While the centralized variant has a significantly lower F1 in most cases, a few examples of the unstressed [τρA] can be seen residing well within the group defined by the stressed instances. Additionally, one instance of the stressed [νAλ] lies within the group defined by the unstressed instances of the vowel. Thus, while there is a visible trend to reduce the vowel quality in unstressed syllables, this trend is not always followed, and may not be a strict condition for stress.

Conclusions

The results of this experiment strongly support the hypothesis that stress in Vlach is produced as a conglomerate of effects that include increasing the stress, intensity, and duration of the syllable, and reducing the quality of the vowel towards mid-central values. The strongest of these effects is pitch; values for peak pitch in stressed syllables were between 20-45% higher than values for unstressed syllables. Duration values also showed significant changes: the stressed syllables [ναλ] and [τυ] were 35% longer than their unstressed counterparts, and the stressed syllables [ιν] and [τρA] were 9% and 13% longer, respectively, than their unstressed counterparts. Intensity also increased, roughly 10%, for stressed syllables.

The effects on vowels were much less consistent, but clearly vowel reduction does occur for unstressed syllables both in initial and final position. The initial [ι] in the [∪ιντρA] / [ιν∪τρA] pair showed the least amount of reduction, while the final [υ] in the [∪ναλτυ] / [ναλ∪τυ] pair, and all instances of the [A] vowels showed clear contrasts between reduced (unstressed) and non-reduced (stressed) variants. However, the [A] vowels showed several examples of crossover between groups, which suggests that the vowel quality is not a restrictive feature of stress production; stress can still be produced even if the vowel quality is not changed in the usual way.

Appendix

Target Sentence

The target sentence was the same as in the previous project:
[αΥ σπυν λ↔καρδιΑ ________ λ ℘ ϖλ↔Σ↔Στ↔]
"I say the word _______ in Vlach."

Wordlist

The wordlist was hand-randomized, consisting of six repetitions of each of the four words [∪ιντρΑ] (he enters), [ιν∪τρΑ] (he entered), [∪ναλτυ] (tall), and [ναλ∪τυ] (he grew). The list below accurately reproduces the list as presented to the speaker.

	Vlach	English
1	naltu	tall (m.)
2	intra	he enters
3	intra	he entered
4	naltu	he grew
5	intra	he enters
6	naltu	tall (m.)
7	naltu	he grew
8	intra	he entered
9	intra	he entered
10	naltu	tall (m.)
11	intra	he enters
12	naltu	tall (m.)
13	naltu	he grew
14	naltu	he grew
15	intra	he entered
16	intra	he enters
17	naltu	tall (m.)
18	intra	he entered
19	naltu	he grew
20	intra	he enters
21	naltu	tall (m.)
22	intra	he entered
23	naltu	he grew
24	intra	he enters

Praat Scripts

In addition to the batch label and batch relabel scripts by Marc Brunelle, I used a script to systematically retrieve the necessary measurements from the labeled sound files. This script is given below.

```
###########################################################################
## Script based on "stress-log" script by Katherine Crosswhite
##
## This script will read all TextGrid and Wav file pairs in the directory
##
## For each TextGrid/Sound pair, the script will measure the duration
## of segments 1 and 2 on tier 1, and measure the mean pitch, peak
## pitch, intensity and F1 and F2 for segments 1 and 2 on tier 2.
##
###########################################################################

##  Specify the directory containing your sound files in the next line:
```

```
    #######################################

    directory$ = "C:\Temp\sounds\"

    #######################################

## Now we will do some prep work to get your log file ready.  The first thing I usually do is
## make sure that I delete any pre-existing variant of the log:
filedelete 'directory$'stress-log.txt

## Output Header Row
     fileappend "'directory$'\stress-log.txt" object_name'tab$'s1_duration'tab$'s1_pitch_peak'tab$'
     fileappend "'directory$'\stress-log.txt" s1_pitch_thru'tab$'s1_amp_mean'tab$'
     fileappend "'directory$'\stress-log.txt" s1_f'tab$'s1_f2'tab$'

     fileappend "'directory$'\stress-log.txt" s2_duration'tab$'s2_pitch_peak'tab$'s2_pitch_thru'tab$'
     fileappend "'directory$'\stress-log.txt" s2_amp_mean'tab$'s2_f1'tab$'
     fileappend "'directory$'\stress-log.txt" s2_f2'newline$'

## Populate list of TextGrid filenames, and count them.
Create Strings as file list...  list 'directory$'\*.TextGrid
number_files = Get number of strings

# Declare Global Variables
    s1_duration   = 0
    s1_amp   = 0
    s1_pitch_peak = 0
    s1_pitch_thru = 0
    s1_f1         = 0
    s1_f2         = 0
    s2_duration   = 0
    s2_amp   = 0
    s2_pitch_peak = 0
    s2_pitch_thru = 0
    s2_f1         = 0
    s2_f2         = 0
    v1_start = 0
    v1_end = 0
    v1_mid = 0
    v2_start = 0
    v2_end = 0
    v2_mid = 0

# Then we set up a "for" loop that will iterate once for every file in the list:
for current_file from 1 to number_files

     # Query the file-list to get the first filename from it, then read that file in:
     select Strings list
     current_token$ = Get string... 'current_file'

     # Read in the TextGrid file, then read the corresponding Sound file
     Read from file... 'directory$'\'current_token$'
     object_name$ = selected$ ("TextGrid", 1)
     Read from file... 'directory$'\'object_name$'.wav

     # Select the TextGrid for the duration analysis
     select TextGrid 'object_name$'

     # TIER 1 = SYLLABLE
     # Measure and record duration of first and second syllables
     number_of_intervals = Get number of intervals... 1
     for b from 1 to number_of_intervals
          interval_label$ = Get label of interval... 1 'b'
          if interval_label$ = "1"

               s1_start = Get starting point... 1 'b'
               s1_end = Get end point... 1 'b'
    s1_duration = (s1_end - s1_start) * 1000

          endif
          if interval_label$ = "2"

               s2_start = Get starting point... 1 'b'
               s2_end = Get end point... 1 'b'
    s2_duration = (s2_end - s2_start) * 1000

          endif
     endfor

     # TIER 2 = VOWEL
```

```
     # Get start and end points for vowels
     number_of_intervals = Get number of intervals... 2
     for b from 1 to number_of_intervals
          interval_label$ = Get label of interval... 2 'b'
          if interval_label$ = "1"

               v1_start = Get starting point... 2 'b'
               v1_end = Get end point... 2 'b'
    v1_mid = v1_start + ( (v1_end - v1_start) / 2 )

          endif
          if interval_label$ = "2"

               v2_start = Get starting point... 2 'b'
               v2_end = Get end point... 2 'b'
    v2_mid = v2_start + ( (v2_end - v2_start) / 2)

          endif
     endfor

          # Measure pitch, intensity, and formants

    # PITCH
    select Sound 'object_name$'
    To Pitch... 0 40 600
    select Pitch 'object_name$'
    s1_pitch_peak = Get maximum... v1_start v1_end Hertz Parabolic
    s1_pitch_thru = Get mean... v1_start v1_end Hertz

    s2_pitch_peak = Get maximum... v2_start v2_end Hertz Parabolic
    s2_pitch_thru = Get mean... v2_start v2_end Hertz

    # INTENSITY
    select Sound 'object_name$'
    To Intensity... 100 0
    select Intensity 'object_name$'
    s1_amp_mean = Get mean... v1_start v1_end
    s2_amp_mean = Get mean... v2_start v2_end

    # FORMANTS
    select Sound 'object_name$'
    To Formant (burg)... 0.01 5 5000 0.025 50
    s1_f1 = Get value at time... 1 v1_mid Hertz Linear
    s1_f2 = Get value at time... 2 v1_mid Hertz Linear
    s2_f1 = Get value at time... 1 v2_mid Hertz Linear
    s2_f2 = Get value at time... 2 v2_mid Hertz Linear

     # Output measurements to file
     fileappend "'directory$'\stress-log.txt" 'object_name$''tab$'
     fileappend "'directory$'\stress-log.txt" 's1_duration:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's1_pitch_peak:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's1_pitch_thru:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's1_amp_mean:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's1_f1:0' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's1_f2:0' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's2_duration:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's2_pitch_peak:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's2_pitch_thru:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's2_amp_mean:1' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's2_f1:0' 'tab$'
     fileappend "'directory$'\stress-log.txt" 's2_f2:0' 'tab$'

     # Output time data (only used for debugging)
     #fileappend "'directory$'\stress-log.txt" 'v1_start:4' 'v1_end:4' 'v1_mid:4' 'v2_start:4' 'v2_end:4'
'v2_mid:4' 'tab$'

     fileappend "'directory$'\stress-log.txt" 'newline$'

     # Clear list (except for file string) and move on to next file.
     select all
     minus Strings list
     Remove
endfor

# cleanup
select all
Remove
clearinfo
print All files have been processed.
```