Project 3: Vlach Affricates, Stops, and Fricatives

Introduction

In this project, I compare affricates to stops and fricatives. In the analysis, the Vlach affricate [τσ] is compared to the stop [τ] and the fricative [σ], and the affricate [τΣ] is compared to the stop [τ] and the affricate [Σ]. The comparison is based primarily on the duration of the consonants: since an affricate consists of a stop followed by a fricative, the first part of the affricate will have durations that can be compared to the stop consonant (e.g. stop closure duration and stop aspiration duration, if any), and the second half of the affricate will have a duration of frication that could be compared to the duration of frication in the fricative consonant.

I expect to find that the total duration of the affricate consonant is less than the sum of the durations of the stop consonant and the fricative consonant, because phonemically they are all consonants (i.e. the affricate is itself a phoneme, not simply an adjunction of a stop phoneme and a fricative phoneme). I suspect that the overall duration of the affricate will be similar to the overall duration of the stop or the fricative; thus I expect to find that the duration measurements of the independent consonants (stop closure duration, stop aspiration duration, and frication duration) will all be shortened.

A second measurement will be made of the peak frication frequency. This should correspond to the place of articulation of the fricative. Thus I expect to find that the frication frequency for the affricate [τσ] is the same frequency as in [σ], and similarly for [τΣ] and [Σ].

The main part of the experiment will consist of looking at these stops, fricatives, and affricates in word-medial position in two-syllable words. In all cases, the consonant in question will be the beginning of the second syllable, which is unstressed, so that a controlled comparison can be made. As a secondary analysis, these results will be compared to stops, fricatives, and affricates in word-initial, stressed position. I do not expect to find any major differences between the word-initial and word-medial position occurrences, except for perhaps a slight lengthening due to stress. If lengthening occurs, this should be the same for all word-initial consonants; thus the comparison between word-initial stops, fricatives, and affricates should be valid.

Methods

Word Lists and Recording

The data was acquired by recording the speaker with a solid-state digital recorder (a 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.

The full wordlist is given in the appendix. It consists of the following words:

Phonetic Transcription:	*English Gloss:*	*Consonant of Interest:*
[∪τAτσι]	"be quiet!"	[τσ]
[∪πατΣ↔]	pig's feet soup	[τΣ]
[∪παΣ↔]	pasha	[Σ]

[∪κΑσ↔]	house	[σ]
[∪τΑτ↔]	father	[τ]
[∪Σαπτι]	seven	[Σ] (word-initially)
[∪τΣαπ↔]	hoe	[τΣ] (word-initially)
[∪τΑτ↔]	father	[τ] (word-initially)

Words were chosen to have two syllables: the first beginning with a stop and the second beginning with a stop, fricative, or affricate for the word-medial measurements; and the first beginning with a stop, fricative, or affricate and the second beginning with a stop for the word-initial measurements. Vowel quality was controlled as much as possible while using real Vlach words. Similarly, the consonants were controlled as much as possible, with the notable exception of [Σαπτι], which contains a consonant cluster at the beginning of the second syllable. No suitable two-syllable word could be found at the time that contained the [Σ] word-initially and a single stop at the start of the second consonant.

The careful choice of words was made to facilitate the use of relative duration measurements; in these measurements the duration of the consonant is compared to the duration of the entire word, thus helping to reduce the effects of speech rate (which can have a significant effect on the absolute duration of a word or any part of the word). In this project, both absolute and relative duration values are used.

Measurements

For each token, the relevant measurements were made from the list below; non-relevant measurements (e.g. frication frequency of a stop) were not recorded. The possible measurements were:

- Word duration
- Frication duration
- Stop closure duration
- Stop aspiration duration
- Frication frequency

Accordingly, each stop had three relevant measurements (word, closure, and aspiration durations); each fricative had three relevant measurements (word and frication duration, and frication frequency); and each affricate had all five relevant measurements. Each word was recorded ten times: with three fricatives at three measurements each (90 measurements), three affricates with five measurements each (150 measurements) and two stops with three measurements each (60 measurements), this gave roughly 300 individual measurements.

From the above measurements, the total duration of the consonant was calculated (frication duration alone for fricatives; closure + aspiration duration for stops; closure + aspiration + frication duration for affricates). This total duration was divided by the word duration to give the relative duration of the consonant.

Frication frequency was determined by a script[1] using Praat's formant-finding capabilities; measurements were taken at two points equally spaced over the fricative duration and then averaged together.

[1] See the appendix for the full script.

Word duration was taken to begin at the release of the initial stop closure[2] and end when the final consonant ended. The first measurement point is rather objective; there is nearly always a clear release point for the initial stop. However, determining the end of the vowel can be subjective, so certain criteria were adopted to control for this. The end of the final vowel was taken to be the point where the first formant and the higher formants begin to disappear: the second (and sometimes third and fourth) formants have a tendency to linger longer into the final aspiration that occurs as the speaker releases excess air after the word.

Frication duration was rather easily measured as starting with the onset of wide bandwidth frication noise, and ending with the disappearance of the same noise. This occasionally left a period of low-amplitude noise that followed the frication but preceded the clear onset of the following vowel, but since this was consistently not included in the measurement, the criterion seems sound.

Stop closure duration is rather easy to measure in word-medial position and does not need to be described much here. See the results section below for a discussion of measuring word-initial stop closures.

Stop aspiration duration was taken to be the period occurring after the visible release burst of the stop but prior to a clear onset of the ensuing vowel formants. This was readily observable in the stop consonant, but not very observable in the affricates. Several affricates had a period of low-amplitude noise following the apparent stop closure release but preceding the onset of high-amplitude, wide-bandwidth noise that signaled the onset of the frication. When this appeared, it was measured as stop aspiration. However, in several instances this phenomenon was not observable; in these cases the stop aspiration was taken to be zero.

Results

The first portion of this section will deal with the results obtained from the word-medial instances of these consonants. Word-initial consonants are discussed further below. Results follow for the key measurements made: consonant duration and fricative frequency.

Results Section 1: Word-Medial Consonants

Frication Frequency

As expected, the frication frequency remained constant between affricates and fricatives. The table below highlights this similarity:

	Alveolar		Post-Alveolar	
	[s]	**[ts]**	**[Σ]**	**[τΣ]**
Mean Frequency:	5555.59	5560.78	4289.98	4260.82

[2] Although this posed a problem for measuring word-initial stops and affricates. See more in the Results section.

Standard Deviation:	136.85	216.61	169.70	174.83

Table 1: Fricative frequency comparison. All frequencies are in Hz.

As the table illustrates, the peak frequency of a fricative consonant or the fricative portion of an affricate is an important measurement that can distinguish between different fricatives (e.g. between an alveolar and a post-alveolar fricative/affricate), yet is consistent between fricatives and affricates with the same place of articulation.

Duration differences between stops, fricatives, and affricates

In the results, affricates showed a reduction in closure time relative to stops, and a reduction in frication time relative to fricatives, with a slight overall increase in total duration of the consonant (with a corresponding increase in the relative duration of the consonant). The table below lists these differences.

	Fricatives		Stops	Affricates	
	[σ]	[Σ]	[τ]	[τσ]	[τΣ]
Closure Duration:	n/a	n/a	96.90	45.56	50.76
Standard Deviation:	-	-	(9.87)	(8.31)	(4.76)
Aspiration Duration:	n/a	n/a	21.13	18.39	5.10
Standard Deviation:	-	-	(5.19)	(9.90)	(3.26)
Frication Duration:	139.46	135.20	n/a	98.36	89.42
Standard Deviation:	(6.47)	(6.91)	-	(9.17)	(9.75)
Total Duration:	139.46	135.20	118.02	162.30	145.29
Standard Deviation:	(6.47)	(6.91)	(11.33)	(9.33)	(8.67)
Relative Duration:	28.58%	32.60%	32.34%	37.89%	35.63%
Standard Deviation:	(2.51%)	(1.63%)	(3.16%)	(2.08%)	(2.90%)

Table 2: Duration differences between fricatives, stops and affricates. All times are in ms.

Below is a graph comparing the durations of the five consonants. The total duration is broken into pre-release (i.e. the closure duration) and post-release (the combined aspiration and frication durations):

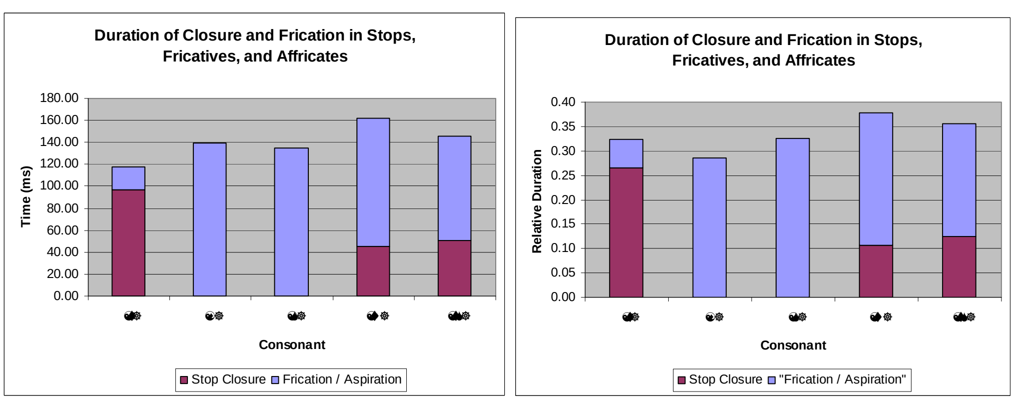


Figure 1: Comparison of consonant durations. Absolute durations are on the left, word-relative durations are on the right.

The figure illustrates the fact that overall, consonant durations are roughly the same, with affricates being slightly longer than stops or fricatives. The absolute values are generally comparable with the relative values.

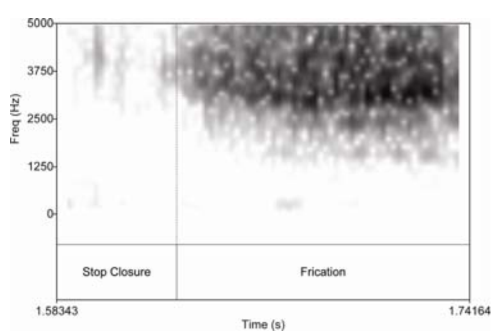
Note the significant reduction in closure duration when comparing a normal stop (97 ms) to an affricate (46ms or 51ms). The duration time of the stop closure in an affricate is roughly 50% that of a normal stop.

There is also a reduction in duration of frication noise, although it is not as drastic as the closure duration reduction. For the alveolar fricative/affricate, there is a reduction in frication duration from 139ms to 98ms (70%), and for the post-alveolar from 135ms to 89ms (66%).

The total duration of the affricate is longer than that of either the fricative or the stop, though not as long as the sum of the two. Because the durations of the individual components are reduced, as described above, the total duration of the affricate is only slightly longer than the duration of a fricative or stop by itself. The alveolar affricate has a total duration of 162ms, 17% longer than the alveolar fricative (139ms), and 37% longer than the alveolar stop (118ms). Similarly, the post-alveolar affricate has a total duration of 145ms, 7% longer than the post-alveolar fricative (135ms) and 23% than the stop (118ms).

Similar calculations can be made to compare the relative duration of the consonant, rather than the absolute duration. The relative duration of the alveolar affricate (38% of total word length) is 31% longer than the relative duration of the alveolar fricative (29% of total word length). Likewise, the relative duration of the post-alveolar affricate (36% of total word length) is 9% longer than the post-alveolar fricative (33% of total word length). The alveolar affricate has a 17% longer duration than the stop, and the post-alveolar affricate has a 10% longer duration than the stop.

One interesting and complicating point is the presence of aspiration after consonants and in affricates. There was a clear, though short, period of aspiration following the release burst of the stop [t]. Furthermore, there sometimes appeared to be a similar, short period of low-amplitude noise following the stop closure in the affricates and preceding the high-amplitude frication noise. However, I am unsure whether to call this aspiration or whether it is simply a brief period of time that is needed to build up enough airflow for frication noise to occur at high amplitudes. Regardless, I measured this time period when it was visible, and it does not play a major role in the analysis a) because it is so small and b) because the overall duration incorporates this duration and so is not affected. When it does appear, it is preceded by a visible burst corresponding to the release of the stop closure. However, in some instances the affricate shows neither a clear stop release nor the ensuing period of low-amplitude noise. Below are spectrograms of the affricate [τΣ] as it was produced in two different recordings of the same word:



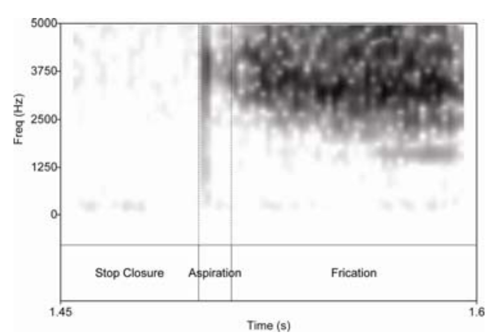


Fig 2: Spectrograms of an affricate with no visible burst (left) and a highly visible burst (right).

As stated above, I do not think it is appropriate to call this aspiration (as it is labeled in the figure), but rather it seems that sometimes the burst is strong, and sometimes is weak or practically nonexistent. Thus, it does not seem that the burst following the stop release is an essential component of the affricate—this could be something to study in a perception experiment.

A final point worth discussing is the marked difference in affricate aspiration duration between [τΣ] and [τσ] that is obvious in table 2 above. The previous paragraph described the different realizations of [τΣ] that were observed, with either a clear burst or no burst. However, the affricate [τσ] was consistently produced with a sort of double burst, which was measured as a stop closure, followed by aspiration, followed by frication. The figure below illustrates this phenomenon:

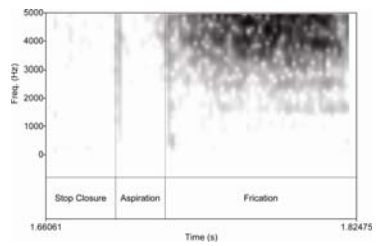


Fig. 3: Affricate [ts] double burst.

As the figure above illustrates, there are in fact two visible bursts: the first is taken to be the release of the stop closure, and the second is taken to be the beginning of the frication noise. This phenomenon was consistently produced for the [τσ] affricate but not for the [τΣ] affricate.

Results Section 2: Word-Initial Consonants

A word of caution: the data for the word-initial consonants are much less reliable than that for the word-medial consonants. The main reason for this is that the speaker often paused before pronouncing the word, which introduces a significant amount of uncertainty into the measurement of the duration of the initial stop closure. Furthermore, since the initial stop closure was not included in the word duration measurements (see the methods section above), this complicated the matter of calculating relative durations of the initial stop closure.

Due to this difficulty, a partial analysis that ignores the effects of stop closure duration, focusing solely on frication, is given below. In this analysis, I use the same criteria as for word-medial consonants, measuring the word duration as beginning at the point where the initial stop closure is released. The frication data, unaffected by the initial stop closure, is sound. At the end of this section, an analysis including the stop closure data is given, although with the caveat that the data may be corrupted.

Fricative Frequency:

Because only the post-alveolar fricative/affricate was measured word-initially, a comparative analysis of alveolar frication to post-alveolar frication can not be carried out. However, the results show a strong correlation between fricative and affricate frequency, and are comparable to the results observed in section 1 above:

	Post-Alveolar	
	[Σ]	**[τΣ]**
Mean Frequency:	4406.21	4369.20
Standard Deviation:	263.01	265.97

Table 3: Frication frequency of word-initial consonants.

Compared to the results obtained for word-medial consonants, the post-alveolar fricatives in word-initial position have a slightly higher mean frequency (by about 150Hz). The standard deviation is also significantly higher than in section 1; since the standard deviation is greater than the difference in mean frequency between word-initial and word-medial fricatives/affricates, not too much should be made of this observation. It may be that the increase in frequency is due to the difference in stressed/unstressed positions, but such a hypothesis would need further data to bear it out (incorporating more than one fricative/affricate and looking at stressed/unstressed positions both word-initially and word-medially).

Frication Duration in Word-Initial Fricatives and Affricates

The table below illustrates the absolute duration of the frication only in the two consonants. Relative values are not included for two reasons: first, relative values were not calculated in section 1 (relative values were calculated only for total consonant duration in the affricate, not for the frication duration independently), so there would be no basis for comparison. Also, the two target words used here were [∪τΣαπ↔] and [∪Σαπτ↔]; the consonant cluster in the second word can be expected to have a longer duration than the single stop in the first word, potentially corrupting any empirical value of the relative duration measurements.

	Post-Alveolar	
	[Σ]	**[τΣ]**
Frication Duration:	130.40	85.34
Standard Deviation:	5.92	10.56

Table 4: Frication Duration in Word-Initial Consonants.

The result here is clearly comparable the result observed in section 1: the frication duration is decreased in the affricate compared to the fricative. Here, the duration of frication in the affricate (85ms) is reduced to 65% that of the affricate (130ms). Recall that the post-alveolar frication duration was reduced similarly to 66% (from 135ms to 89ms) in the word-medial position. Thus it would seem that word position and stress have little effect on the duration of frication in post-alveolar fricatives and affricates.

Stop Duration in Word-Initial Stops and Affricates

For the reasons mentioned above, this data should be considered unreliable. However, it is included here for completeness. One set of data with an especially egregious pause was removed prior to calculation of these values, but even for the data which are presented here, problems remain. Below is a table illustrating the stop closure duration and aspiration duration in word-initial stops and affricates:

	Word-Initial		
	[τ]	**[Σ]**	**[τΣ]**

Aspiration Duration:	23.89	n/a	n/a
Standard Deviation:	3.56	n/a	n/a
Stop Closure Duration:	126.56	n/a	54.95
Standard Deviation:	23.98	n/a	17.83
Frication Duration:	n/a	130.40	85.34
Standard Deviation:	n/a	5.92	10.56
Total Duration:	150.46	130.40	140.29
Standard Deviation:	21.28	5.92	26.35
Relative Total Duration:	40.71%	24.69%	33.58%
Standard Deviation:	6.24%	1.13%	5.95%

Table 5: Durations in Word-Initial Consonants

Below is a figure that illustrates the differences in duration of the three consonants:

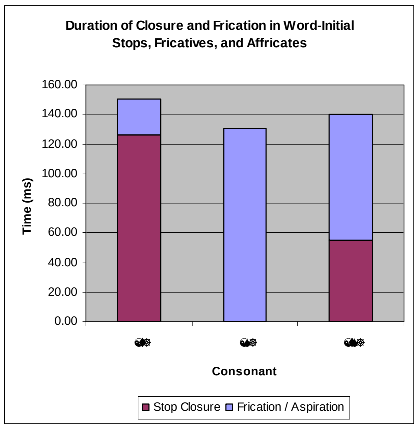


Fig. 4: Duration of stop closure and frication/aspiration of [t] [s] and [ts].

This figure shows a similar trend as figure 1(the duration values for word-medial consonants), although here the stop closure measurements must be considered unreliable, resulting in an overall longer length for the [t] values. Notice, however, that the stop aspiration duration is comparable to that observed in results section 1 above; this is not significant for the analysis, but it is encouraging to see consistency where we expect to see it, even if the stop closure measurements are corrupted.

Next, consider the total duration (and total relative duration) measurements. Similarly to the previous section, all of the consonants have a similar duration, and the fricative is slightly longer than the affricate (140ms rather than 130ms). This 8% increase is very comparable to the 9% increase seen in results section 1 for the word-medial consonant. Unexpected is the fact that the total stop duration (150ms) is 7% longer than the total affricate duration (140ms). Quite the opposite result was seen above, where the same comparison showed the affricate duration 23% longer than the stop duration. I suspect that this has to do with the excessively long stop closure of the word-initial stops, described elsewhere in this paper. However, I cannot explain why this lengthening should apply to the stop consonant but not to the affricate. The stop closure duration here word-initially is 127ms, compared to 97ms for the same duration word-medially, a 31% increase. However, the stop closure duration in the affricate word-initially is 55ms, compared to 51ms in the word-medial measurements, only an 8% increase. This is somewhat puzzling, but I suspect it is at least partly due to the inconsistent inter-word pausing that the speaker displayed.

Looking beyond these inconsistencies, the word-initial analysis is quite similar to the word-medial analysis. Further recordings, with special emphasis on avoiding the inter-word pauses, could help reveal to what extent, if any, the lengthening of the stop closure in the stop consonant is a valid feature of word-initial, stressed consonants and not simply due to pauses between words. This might also help explain why this lengthening occurs only for the initial stops, and not the initial affricates.

Difficulties

I would identify three major points of difficulty in this project. One has to do with the recording, one with the measurements, and one with the analysis.

First of all, I feel that the recordings made for this project were less than perfect, although, with the exception of the word-initial stops, the results of the experiment seem to be fairly sound. Nevertheless, during the recording session, there were several points where the speaker stumbled over his words and mispronounced the target words (e.g. saying [∪κΑΣ↔] for [∪κΑσ↔] in multiple instances). I attribute this to many factors, including the repetitive nature of the word list and the high degree of similarity in the target words. However, I also think that the printed list I used to prompt the speaker was flawed: I should have used a phonemic transcription rather than a phonetic transcription, in order to mask the underlying nature of the affricates. Furthermore, I used the random number function in Excel to randomize my wordlist; I feel that this was actually worse than a pseudo-random wordlist. It seemed that there were too many instances of the same word being repeated twice or even three times sequentially, and these were exactly the places where many of the speaker's mistakes occurred. Furthermore, the list concentrated some words heavily near the end and others near the beginning of the list; thus, the words were not uniformly distributed over the recording session and factors such as fatigue may have played a role in the results. In future projects I will use a pseudo-random or locally-randomized wordlist.

A second complication had to do with measuring word-initial stop closures. This was discussed above, and I think the best solution is to have a frame sentence that will highlight the distinction between the previous sound and the stop closure (in fact, this was not a problem with my frame sentence), and also to encourage the speaker to say the entire frame sentence at a constant pace. The speaker in this experiment had a tendency to pause before and after the target words so as to highlight it; this resulted in exceptionally long silence before the target word which made it difficult to measure the initial stop closure. Even with a constant pacing throughout the sentence, though, there will still be a slight additional pause between words.

The final complication also had to do with the issue of word-initial stops. The point of release of the word-initial stop closure was chosen as a very identifiable point to measure the beginning of the word, specifically to avoid the problem of the pre-release closure and inter-word pauses. However, this led to difficulties when trying to measure the relative duration of word-initial stop closures: if the stop closure is not considered part of the word duration, then the relative duration calculations are meaningless (in one instance, the relative duration of the closure was over 100%: it was longer than the duration of the entire word! This was of course due to the speaker's pause before pronouncing the target word).

These last two difficulties could have been anticipated ahead of time, and in fact they were: my original conception of the experiment did not include the word-initial consonants for exactly the reasons above. However, I decided to add them to give an additional dimension to the analysis and to have more tokens to include in the data. In fact, I am not sure this was necessary and ultimately it may have added unnecessary confusion to the analysis.

Conclusions

The data in this experiment overall bore out the hypothesis regarding affricates, stops and fricatives. As hypothesized, the affricate was seen to consist of elements of the stop consonant (specifically, a stop closure followed by a release burst) and elements of a fricative consonant, and the duration of these elements was noticeably decreased in the affricate consonant, giving the affricate a total duration roughly equivalent to the total duration of the stop and fricative consonants.

The peak frication frequency in each affricate (alveolar and post-alveolar) was statistically identical to the peak frication frequency in the corresponding fricatives. There was a slight, nearly insignificant increase in fricative frequency of the word-initial, stressed instances of [Σ] and [τΣ] ([s] and [ts] were not measured word-initially) compared to the word-medial, unstressed instances. The increased frequency may be due to some aspect of stressing in Vlach, but this needs further analysis, as outlined above in the results section.

Another area that warrants further analysis is the nature of the stop release in these affricates. It was seen that the stop release burst for [τΣ] is sometimes very pronounced and sometimes completely invisible. In most cases, the release was prominent, and it would be worth investigating whether the burst is preferred or necessary for perception, as well as what factors contribute to its production (fatigue may be a factor, since it seems that most of these non-burst affricates occurred near the end of the recording session). Furthermore, the double burst phenomenon in the [ts] affricate is interesting in itself, and could also be investigated as a perceptual experiment.

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 consists of seven words repeated ten times each. The word [∪τΑτ↔] does double duty since it is used as an example of a word-initial stop as well as a word-medial stop. The list was randomized in Excel: each row was assigned a random number using the RAND() function, and then the list was sorted based on this number.

1	[∪τΣαπ↔]	hoe	26	[∪τΣαπ↔]	hoe
2	[∪κΑσ↔]	house	27	[∪πατΣ↔]	pig's feet soup
3	[∪παΣ↔]	pasha	28	[∪πατΣ↔]	pig's feet soup
4	[∪τΣαπ↔]	hoe	29	[∪κΑσ↔]	house
5	[∪Σαπτ↔]	seven	30	[∪τΑτ↔]	father
6	[∪κΑσ↔]	house	31	[∪πατΣ↔]	pig's feet soup
7	[∪τΣαπ↔]	hoe	32	[∪τΣαπ↔]	hoe
8	[∪τΑτ↔]	father	33	[∪τΣαπ↔]	hoe
9	[∪παΣ↔]	pasha	34	[∪κΑσ↔]	house
10	[∪τΑτσι]	"be quiet!"	35	[∪τΑτ↔]	father
11	[∪κΑσ↔]	house	36	[∪τΣαπ↔]	hoe
12	[∪τΑτσι]	"be quiet!"	37	[∪παΣ↔]	pasha
13	[∪πατΣ↔]	pig's feet soup	38	[∪παΣ↔]	pasha
14	[∪Σαπτ↔]	seven	39	[∪παΣ↔]	pasha
15	[∪κΑσ↔]	house	40	[∪τΑτσι]	"be quiet!"
16	[∪τΣαπ↔]	hoe	41	[∪Σαπτ↔]	seven
17	[∪τΣαπ↔]	hoe	42	[∪κΑσ↔]	house
18	[∪Σαπτ↔]	seven	43	[∪κΑσ↔]	house
19	[∪πατΣ↔]	pig's feet soup	44	[∪παΣ↔]	pasha
20	[∪πατΣ↔]	pig's feet soup	45	[∪τΑτ↔]	father
21	[∪τΑτσι]	"be quiet!"	46	[∪τΑτσι]	"be quiet!"
22	[∪τΑτσι]	"be quiet!"	47	[∪Σαπτ↔]	seven
23	[∪Σαπτ↔]	seven	48	[∪τΑτ↔]	father
24	[∪τΑτσι]	"be quiet!"	49	[∪τΑτ↔]	father
25	[∪τΣαπ↔]	hoe	50	[∪Σαπτ↔]	seven

51	[∪κΑσ↔]	house	61	[∪τΑτσι]	"be quiet!"
52	[∪τΑτ↔]	father	62	[∪τΑτσι]	"be quiet!"
53	[∪Σαπτ↔]	seven	63	[∪τΑτ↔]	father
54	[∪πατΣ↔]	pig's feet soup	64	[∪Σαπτ↔]	seven
55	[∪πατΣ↔]	pig's feet soup	65	[∪πατΣ↔]	pig's feet soup
56	[∪τΑτσι]	"be quiet!"	66	[∪Σαπτ↔]	seven
57	[∪πατΣ↔]	pig's feet soup	67	[∪κΑσ↔]	house
58	[∪παΣ↔]	pasha	68	[∪παΣ↔]	pasha
59	[∪τΑτ↔]	father	69	[∪παΣ↔]	pasha
60	[∪παΣ↔]	pasha	70	[∪τΑτ↔]	father

Praat Scripts:

In addition to the label and relabel scripts by Marc Brunelle, I modified a script to measure the various durations in the labeled TextGrid file, as well as to measure the peak frequency of the frication noise using the formant function. The frication noise is measured at two points in the duration of the fricative and averaged together before being output by the script. Below is the text of this script:

```
#################################################################################
## Script based on "duration-log" script by Katherine Crosswhite
##
## This script will read all TextGrid and Wav file pairs in the directory
##
## For each TextGrid, the script will output the duration of every labeled
## interval on the first two tiers.
##
## For each Sound, the script will output the peak frequency of the interval
## labeled "fricative"
#################################################################################

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

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

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

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

##  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$'duration-log.txt

##  Now I'm going to make a variable called "header_row$", then write that variable to the log file:
header_row$ = "Filename" + tab$ + "Word Dur." + tab$ + "Closure Dur." + tab$ + "Aspiration Dur." +
tab$ + "Fric. Dur" + tab$ + "Fric. Freq" + newline$
header_row$ > 'directory$'\duration-log.txt

##  Now we make a list of all the text grids in the directory we're using, and put the number of
##  filenames into the variable "number_of_files":
Create Strings as file list...  list 'directory$'\*.TextGrid
number_files = Get number of strings

# Declare Global Variables
fric_start = 0
fric_end = 0
word_duration = 0
fric_duration = 0
fric_freq = 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)

fileappend "'directory$'\duration-log.txt" 'object_name$''tab$'

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

#  Now we figure out how many intervals there are in tier 1, and step through them one at a time.
#  If an intervals label is non-null, we get its duration and write it to the log file.
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$ = "Word"
          begin_word = Get starting point... 1 'b'
          end_word = Get end point... 1 'b'
          word_duration = (end_word - begin_word) * 1000
         fileappend "'directory$'\duration-log.txt" 'word_duration:2''tab$'
     endif
endfor

# Repeat for tier 2 (stop closure)
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$ = "stopC"
          begin_vowel = Get starting point... 2 'b'
          end_vowel = Get end point... 2 'b'
          duration = (end_vowel - begin_vowel) * 1000
         fileappend "'directory$'\duration-log.txt" 'duration:2''tab$'
     endif
endfor

# Repeat for tier 2 (stop aspiration)
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$ = "stopA"
          begin_vowel = Get starting point... 2 'b'
          end_vowel = Get end point... 2 'b'
          duration = (end_vowel - begin_vowel) * 1000
         fileappend "'directory$'\duration-log.txt" 'duration:2''tab$'
     endif
endfor

# Repeat for tier 2 (frication)
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$ = "fricative"
          fric_start = Get starting point... 2 'b'
          fric_end = Get end point... 2 'b'
          fric_duration = (fric_end - fric_start)
          duration = fric_duration * 1000
         fileappend "'directory$'\duration-log.txt" 'duration:2''tab$'
     endif
endfor

# Calculate two points over frication
fric_p1 = fric_duration / 3 + fric_start
fric_p2 = (2 * fric_duration) / 3 + fric_start

# Select sound
select Sound 'object_name$'

# Create Formant object (only one formant = peak noise frequency)
To Formant (burg)... 0.01 1 10000 0.025 50
select Formant 'object_name$'

# Get formant frequency at two points
fric_f1 = Get value at time... 1 'fric_p1' Hertz Linear
fric_f2 = Get value at time... 1 'fric_p2' Hertz Linear

# Average frequency values
fric_freq_avg = (fric_f1 + fric_f2) / 2
```

```
     # Output
     fileappend "'directory$'\duration-log.txt" 'fric_freq_avg:2'

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

     #  By this point, we have gone through all the intervals for the current
     #  textgrid, and written all the appropriate values to our log file.  We are now ready to go on
to
     #  the next file, so we close can get rid of any objects we no longer need, and end our for loop

     select all
     minus Strings list
     Remove
endfor

# And at the end, a little bit of clean up and a message to let you know that it's all done.

select all
Remove
clearinfo
print All files have been processed.  What next?

## written by Katherine Crosswhite, fixed by Marc Brunelle (mbrunell@umich.edu)
## crosswhi@ling.rochester.edu
```