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grammar of the language published in 1984. Cook (1984) suggests that the Tsuut'ina vocalic system consists of four vowels: / i, a, o, u /. Cook states that the front vowel in Tsuut'ina is a front high vowel that it tends to be lowered to / e / or / ε /, and that "the nearer to final position the syllable is, the more likely [the lowering rule] is to apply" (16).

Although the analysis provided by Cook is very thorough in some places, the grammar's treatment of the vocalic system has some shortcomings. The grammar does not provide any acoustic information regarding the vowels of the language and refers to them using only symbols which are themselves not rigorously defined. The purpose of this paper is to investigate the vocalic system of Tsuut'ina. This study will limit itself to a description of steady-state properties of the vowels with the intention of arriving at a basic description of the size and organization of the vocalic system. Some possible phonological effects will also be considered. Finally, there will be a brief examination of a possible tone or pitch accent system.

Data Co ection

An adult male speaker, HC, participated in an interview session on two separate days. Excerpts corresponding to roughly the first 30 minutes of each session were used for this paper. Formant frequencies (F1, F2, F3) and f0 were collected from the midpoint of each vowel in the recordings. All vowels were plotted according to their F1 and F2 values, as demonstrated in Figure 1. A visual inspection suggested that there were between 3 and 4 vowel phonemes in Tsuut'ina: a front vowel, a back vowel and one or two low vowels (the low vowel looks a bit like two, almond-shaped distributions that meet on F2).

In order to assume as little as possible about the Tsuut'ina vocalic system, all vowels were coded as belonging to one of three possible vowel categories. All front vowels were labeled , all low vowels were labeled   and all back vowels were labeled *u*. The general vowel category a token belonged to was determined by jointly considering Tsuut'ina orthography (if available), and the author's impressions of the vowels.

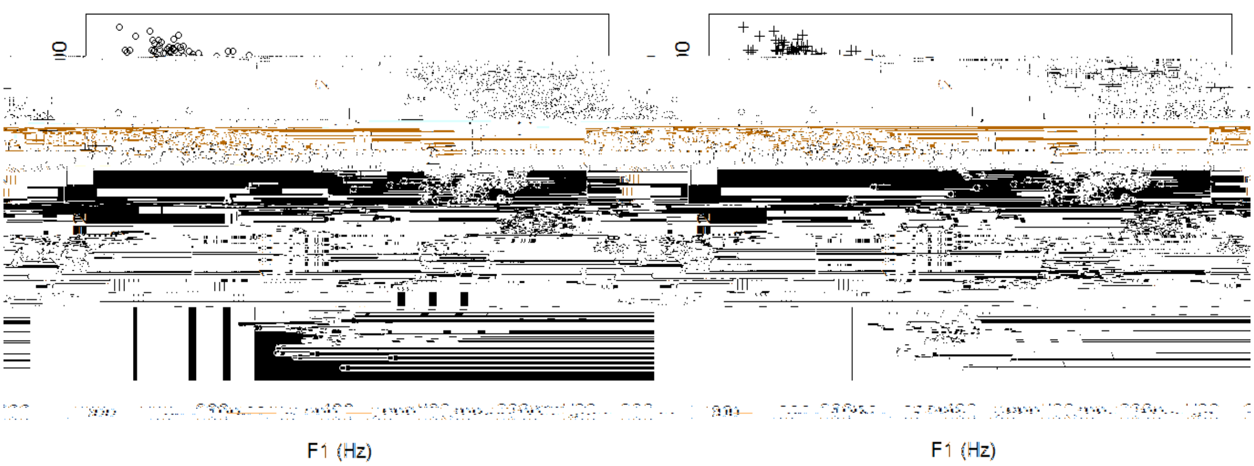

Figure 1 –All vowel tokens collected for speaker HC. In the right panel, vowels are labeled according to gross type: low vowel 'a' (circle), front vowel 'i' (cross), back vowel 'u' (triangle).

All vowels were plotted on an F1-F2 plane, labeled according to their general vowel category. The plot was inspected visually to see if there were any tokens that were dramatically different from vowels of the same category. Most measurement errors were a result of overly breathy, whispered, quiet or muttered vowels. This is partly a result of the way in which the data of back vowels in the language seems to be an inherent property of the language and not a chance occurrence.

3.1.1 Front Vowels

To see if the front vowel in Tsuut'ina has a relatively higher F1 (meaning it is a lower vowel) when it is nearer to the end of the word, all front vowels were given a score corresponding to how far (in syllables) they appeared from the final syllable of the word. This will be referred to as the end-distance. As seen in Table 2, the number of front vowels with and end-distance of 3 is much smaller than the number of vowels with an end-distance of 2. Furthermore, the number of unique words which contain these tokens tends to be quite small for end-distances higher than 2.

is higher along F1. Both of these observations support the claim that the Tsuut'ina front vowel tends to get lowered when it is nearer to the end of the word. Another possibility is that, rather than being progressively lower as they are found closer to the end of the word, there is simply a phonological distinction between word-final and non-word-final vowels.

In order to test this, a series of linear mixed-effects model was fit to each vowel's F1 frequency. The word which included the vowel and the unique repetition of the word were included in all models as random effects. The models differed from each other only in terms of their fixed effects. Random slopes and intercepts were calculated for all fixed effects for all models. The first model was an intercept-only model. This model will be able to account for random differences in F1 resulting from the word and repetition a vowel is found in, but not for any variation resulting from the position of the vowel in the word. This will be the best-fitting model if the Tsuut-ina front vowel shows no systematic variation of front vowel F1 by word-position. The second model included an intercept term and also information regarding whether the vowel was word-final or not. This will be the best-fitting model if front vowels tend to be lowered in final position, but there is no progressive lowering of vowels as they approach the end of the word. The final model included an intercept, and information about the exact distance between the vowel and the end of the word, measured in syllables (end-distance). This will be the best-fitting model if front vowels get progressively lower when they are nearer to the end of the word. A comparison of these three models is provided in Table 3.

Mode fixed effects	**AIC**	**Log Like ihood**	**d f**	**P va ue**
Intercept only	5268	-2630.0	4	--
Intercept + final vowel	4958	-2470.1	9	<.00001
Intercept + end distance	4905	-2436.5	16	<.00001

Table 3 - Comparison of three models fit to front vowel F1 frequencies. Differing fixed-effects between models are described in the0(t)-22(h)20 2 re f 2114 5 be-10(o)-1342582 179863( )-10.64 374.64 Tm ( )Tj

each panel of Figure 4. This line was chosen because it visually bisects the mass of low vowels. For the sake of brevity, low vowels with a F2 higher than 1212 Hz will be referred to as   while those with a F2 lower than 1212 Hz will be referred to as *o*. Figure 4 plots the low vowels with F1 along the y-axis and F2 along the x-axis. The first two formants were represented on different axes for this chart to maximize the difference between the two hypothesized clusters given that they vary mostly along F2. The bottom panel of Figure 4 shows the density of all low vowels along F2. The vowels are distributed bimodally in a manner which supports the notion that could there are two separate, low-vowel phonemes.

To test whether the low vowels sampled could be said to come from two different phoneme populations, I looked at which words contained each of the two hypothesized vowels,   and *o*. The reasoning behind this was that if the sets of words that contained each of the two low vowels were disjoint then they could be said to belong to separate categories. In the case where one word contained two low vowels, if any given vowel belongs to either one or the other set on a consistent basis then two low vowel categories would also be supported.

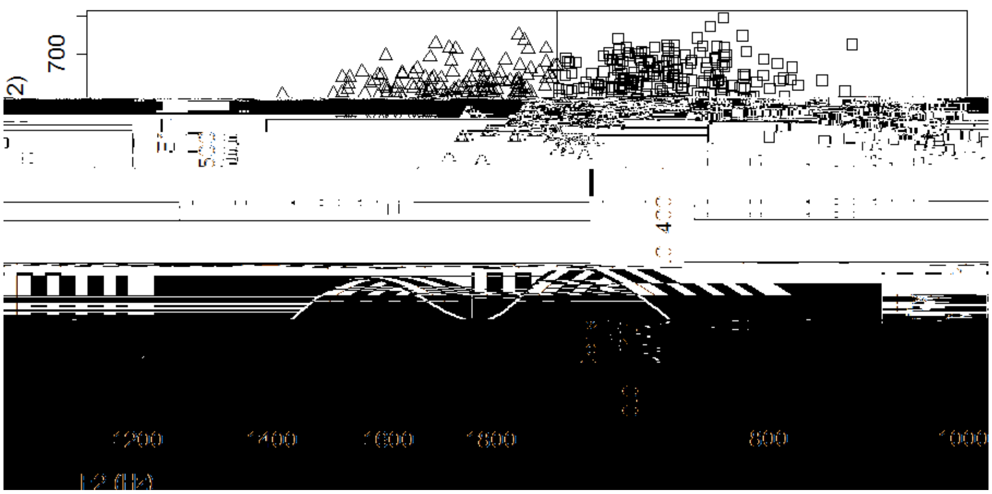

Figure 4 – Top Panel: Low vowels plotted with a tentative phonemic dividing line at F2 = 1212. Vowels with F2s lower than this have been indicated with triangles, those with higher F2s with squares. Hz. Bottom Panel: Kernel density estimates of values of F2 for low vowels with the same tentative phonemic dividing line at 1212 Hz.

Lists were created of all the unique words contained which contained at least one instance of either   or *o*. These two lists were compared yielding three different classes of words: 38 which only contain , 15 which only contain *o*, and 25 which contain both vowels. Only ten of the 25 words that contain both   and *o* were repeated at least three times; these are presented in Table 4. Words will be presented using Tsuut'ina orthography, which is based on English orthography. Tsuu'tina words presented as examples will not be glossed for the most part.

The words in Table 4 can be split into two classes: those that show a clear preference for either *o* or   and those that show variation between the two. The first group has been placed on the left side of Table 4 while the second group has been placed on the right side of the Table. To investigate this variation further, the five words which exhibit low-vowel variation were plotted so that this variation could be investigated visually. Only the low vowels within each word were plotted and the vowels were labeled with numbers that correspond to the syllable in which the vowel is found. This was done to see if words that contained multiple low vowels had a clear preference for one vowel to be *o* and for another to be . Additionally, a horizontal line was placed at 1212 Hz. These plots are presented in Figure 5.

	<u>**a**</u>	<u>**o**</u>		<u>**a**</u>	<u>**o**</u>
dasha	1	10	sinahanilada	15	5
disha	1	11	nik'ada	14	12
nasaa	9	1	nahila	3	3
nitsit'a	1	3	nina	3	5
siza	4	1	tsa	10	6

Table 4 – All words containing both /a/ and /o/ that were repeated at least three times.

Figure 5 – Plots of the low vowels for multiple repetitions of selected words. In the first four panels, labels correspond to the syllable a vowel is found in, counting from the beginning of the word. In the final panel, labels correspond to the session in which the vowel was collected.

The first three words, *s n n* , *n* and *n* show clear preferences for one vowel or another in specific syllable positions. The case of *s n n* is particularly interesting because a vowel in the middle of the word is consistently different, over five repetitions, from the other three low vowels that surround it. Furthermore, *n* preferentially has an in final position while *n*

The final word in Figure 5, *ts* , might at first seem to go against the idea that there are two low vowel phonemes in Tsuut'ina. However, repetitions of this word are actually made up of two similar words, *ts* , which means 'ear' and *tso* which means 'hair'. Instances of the low vowels in the final pane of Figure 4 have been coded according to the session in which they were collected. The majority of instances of this word that contain an *o*-like vowel come from the first session and were recorded in succession. All words that contain an

Mithun, Marianne (1999). *n u s of n t v ort A r* . Cambridge, UK: Cambridge University Press.

Sapir, E. (1925). Pitch accent in Sarcee. *ourn o t s A r n st s r s* 17: 185-205.