

# ACOUSTIC PHONETIC ANALYSIS AS A MEANS OF DEFINING THE PHONEMIC INVENTORY: EVIDENCE FROM THE VOWEL SPACE IN TSUUT'INA

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## 1 Introduction

The phonemic inventory of Tsuut'ina, an Athabaskan language, has a distinct and diverse catalogue of consonants with well-defined features and articulations. The language also contains a phonemic tonal and vowel length system. However, much has been questioned about the vowel space of the language. A traditional analysis of the language's vowel inventory (*a la* Cook 1971 & 1984, and Li 1930) is largely based on word lists, speaker intuitions, and finding vocalic minimal pairs. Following from this linguistic evidence, the Tsuut'ina vocalic space is thought to be divided into four distinct phonemes: /a/, /i/, /o/ and /u/.

This paper explores an alternative method to these traditional means of dividing up a language's vowel space. Rather than relying on the orthography in grammars and speaker intuitions, the analysis presented here relies on exploratory methods in acoustic phonetics. In this study, speakers of Tsuut'ina are recorded, and each vowel they produce is measured for its formants, duration, pitch, and lexical measurements of phonetic environment and syllable structure. These measures are then evaluated independently and across speakers to gain a better understanding of the phonemic division within the Tsuut'ina vowel space.

## 2 Methodology

The method used in this study follows in the tradition of vowel space measurement through formant plotting (see Peterson & Barney 1952). Three adult female speakers, Speaker A, Speaker B, and Speaker J, were each recorded in two 30 minute conversational field sessions. Every Tsuut'ina vowel a speaker produced was tagged, yielding a total of 786 usable vowel tokens. Several vowels had to be discarded due to either recording quality or indistinguishable speech. Each vowel token was then hand measured by a trained phonetician for its duration, and the surrounding phonemic and prosodic environment was transcribed. F0, F1, F2, and F3 values were taken at the middle of the hand marked durations using Praat's automatic formant extractor (Boersma & Weenink 2009) and checked over by hand. The F0 values for each speaker were divided into thirds, resembling the phonemic pitch categories in Tsuut'ina: high tone, mid tone, and low tone. Likewise, the vowel durations for each speaker were dichotomized into long and short lengths, resembling the phonemic vowel length categories. The log transformed F1 value, or G1, was plotted against the log transformed F2 value, or G2, [henceforth, a (G1, G2) plot], and analyzed according to the aforementioned acoustic and lexical parameters.

### 3 Results

#### 3.1 Overall Vowel Space

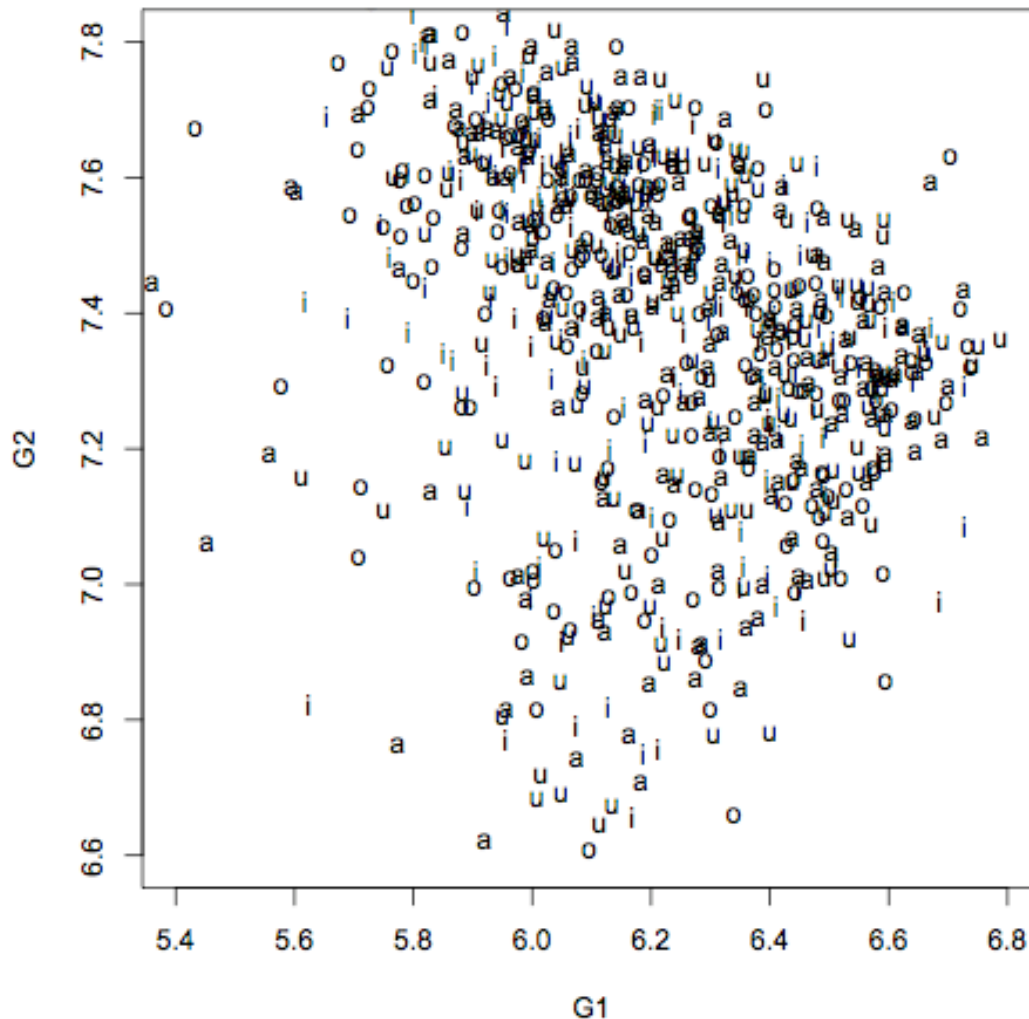


Figure 1 – (G1, G2) for every vowel, coded by the orthographic vowel representation

Figure 1 displays a normalized plot of every vowel across all speakers. The vowels are coded by the orthographic standards found in the Tsut'ina grammar. Here, there are three general vowel spaces that are predominant: front high (mostly “i”), back high (mostly “o” and “a”), and low (mostly “o” and “u”). This initial finding of only three predominant vowel spaces runs contra to the grammatical findings of Cook and Li. However, this sideways “v” shape is only more evident when plotted by speakers, below.

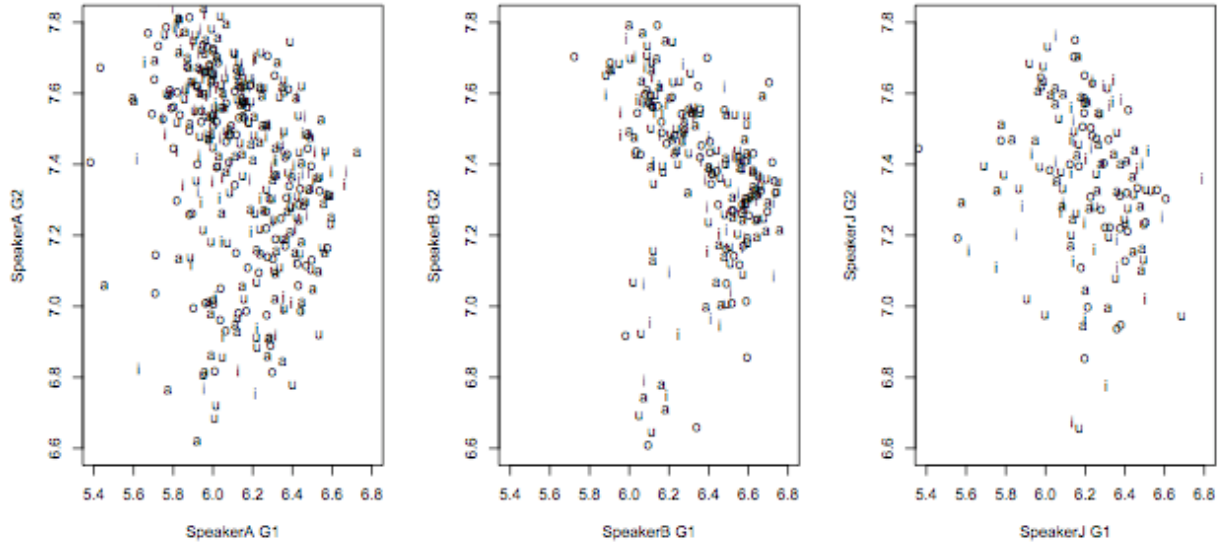


Figure 2 – (G1, G2) for every vowel, grouped by speaker, and coded by the orthographic vowel representation

Here, the vowel space of Speaker B seems to be well-defined in terms of the three vowel phonemic system mentioned above. Additionally, Speaker A's vowel space closely resembles that of Speaker's B with a bit more scattering, hinting towards an effect of vowel centralization (or schwa production) by the speaker. The vowel space of Speaker J, on the other hand, does not seem to have much regularity. Any sort of phonemic vowel space distinction for Speaker J might only be made between one high vowel and one low vowel. The similarities between Speaker A and Speaker B and their dissimilarity with Speaker J are better seen when plotted together, as shown below.

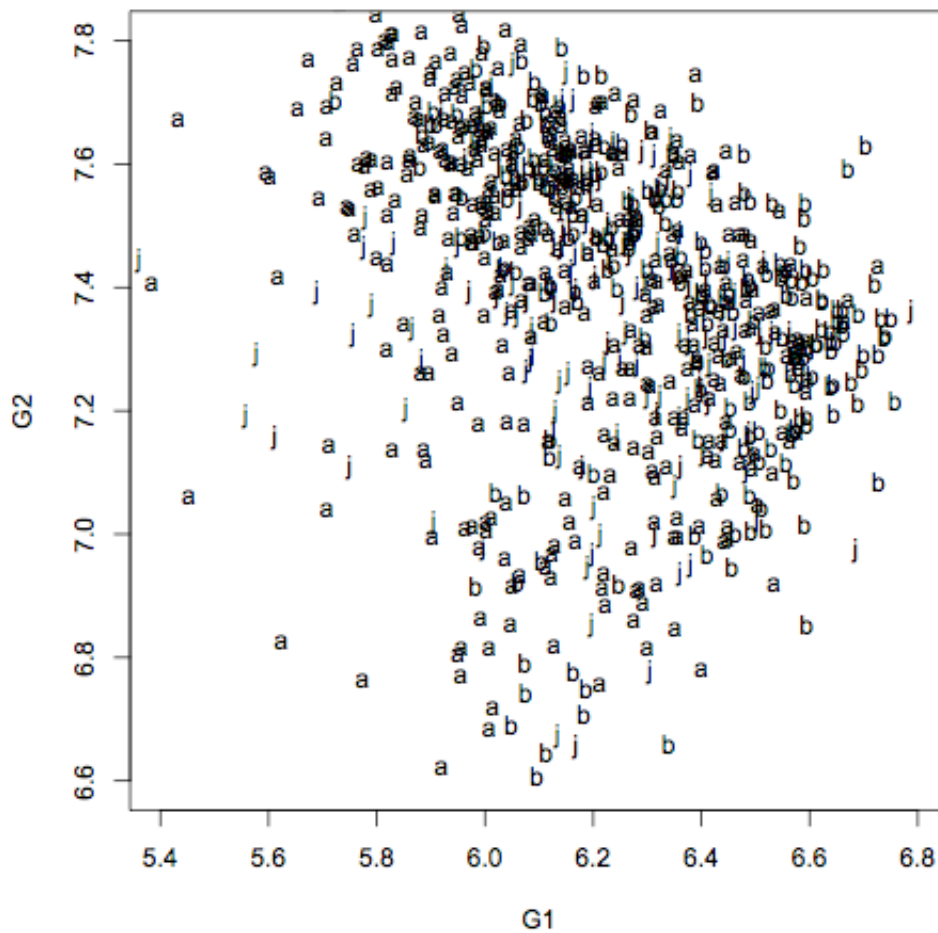


Figure 3 – (G1, G2) for every vowel, coded by speaker: Speaker A is denoted as “a”, Speaker B is denoted as “b”, and Speaker J is denoted as “j”

Figure 3 normalizes each speaker’s vowels and plots them on top of one another, illustrated in symbol form and in color form. Here it is evident just how similar Speaker A (in red) and Speaker B (in black) pattern together in a three vowel phonemic system, while Speaker J (in green) mostly only follows the high/low vowel space trend. Though the plots seen here support a three vowel phonemic system over the traditional four vowel phonemic system, the remaining results presented in this section will start with the assumption of a traditional four vowel phonemic system. Doing so allows for the testing of a hypothetical four vowel phonemic system. It is possible that the lower two vowels (/a/ and /o/) mesh together, and certain phonetic and phonological parameters may tease apart and distinguish the two spaces. The rest of this section addresses these different acoustic and phonological parameters, with an overall discussion of the Tsuut’ina vowel space at the conclusion.

### 3.2 Word Position

Word position, as it is used here, is defined as the ratio of the phonological syllable position (or number) in which a vowel resides to the total number of syllables in the particular word, rounded to the nearest one hundredth of a decimal. For instance, if the vowel resides in the second syllable of a word that has a total of three syllables, its word position would be .67, or 2:3. This measurement provides a convenient way of looking at both a normalized word length and any relation to a vowel's space and its situation in the word (as opposed to its situation in the immediate surrounding context, to be looked at under Phonemic Environment below). The numerical values of word position roughly stand for word initial (i.e.  $x < .5$ ), word medial (i.e.  $.25 < x < .75$ ), and word final (i.e.  $x=1$ ). The plots for each vowel by syllable position, grouped by speaker, are below in figures 4-7.

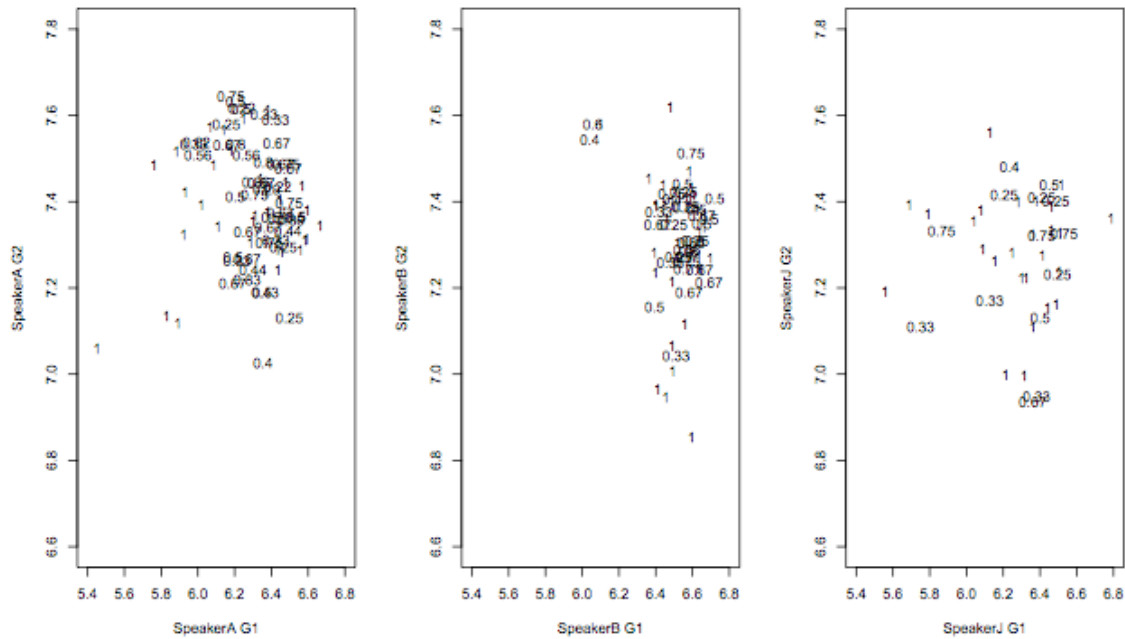


Figure 4 – (G1, G2) for /a/, labeled by word position, grouped by speaker

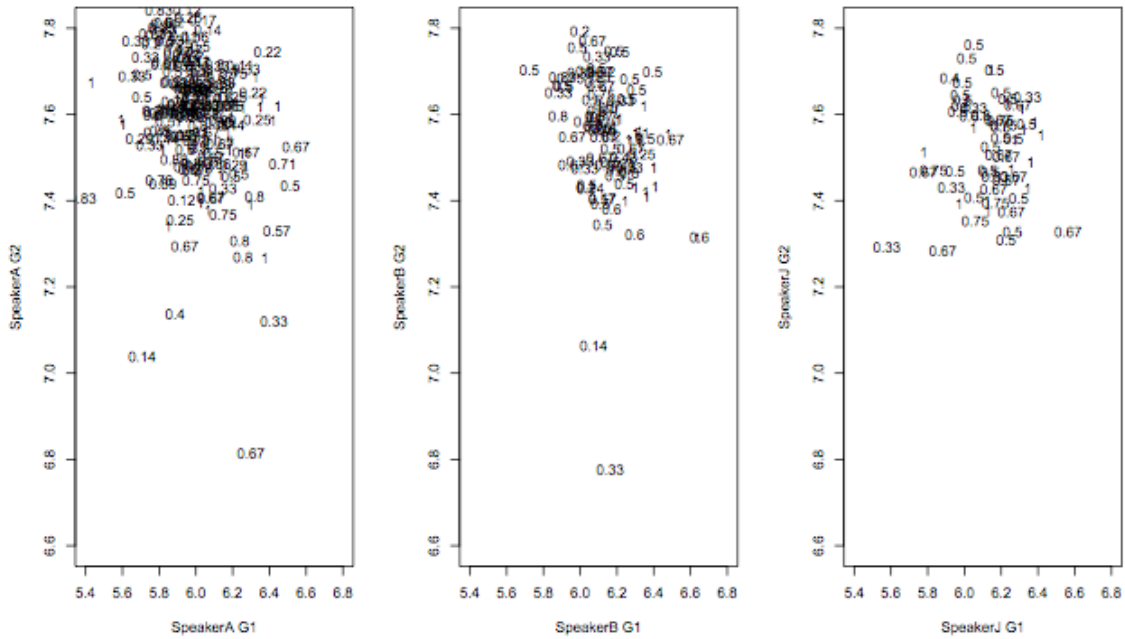


Figure 5 – (G1, G2) for /i/, labeled by word position, grouped by speaker

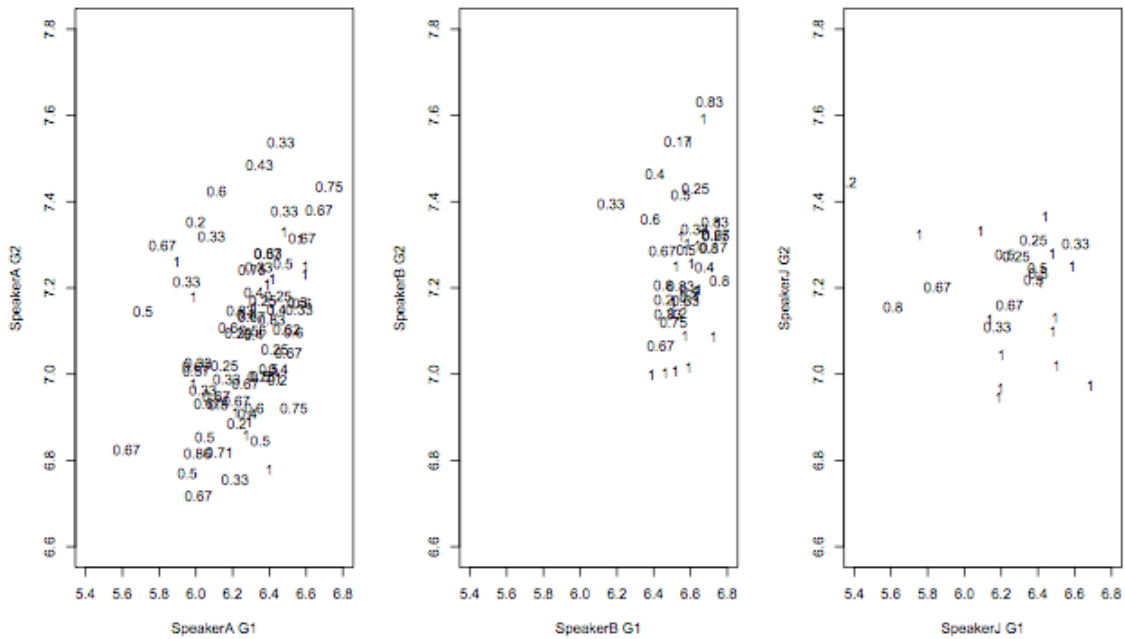


Figure 6 – (G1, G2) for /o/, labeled by word position, grouped by speaker

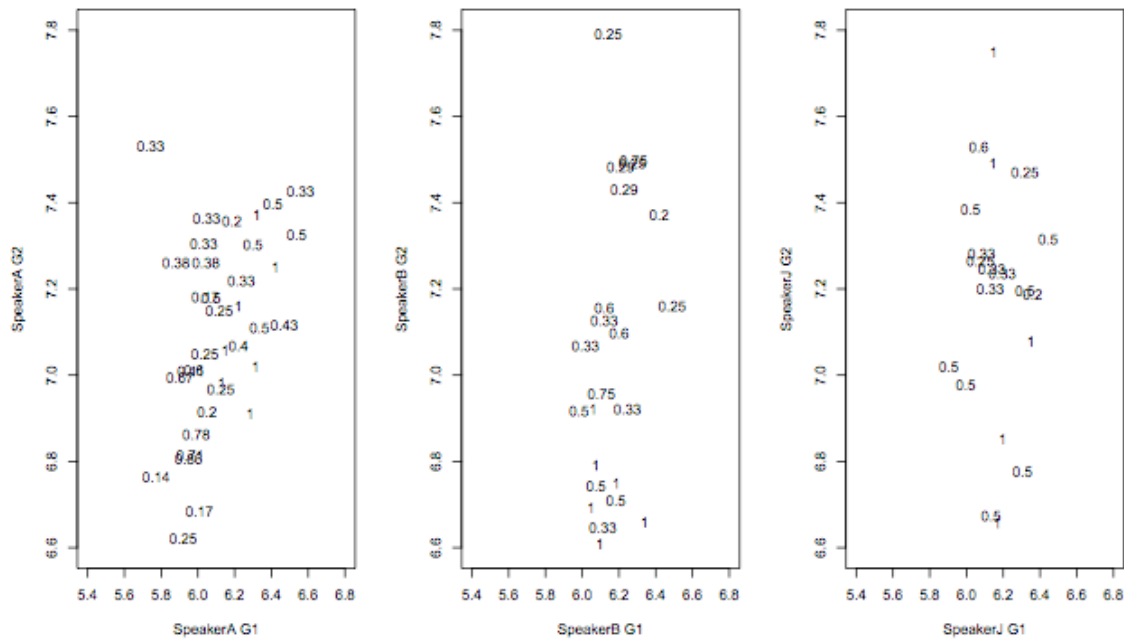


Figure 7 – (G1, G2) for /u/, labeled by word position, grouped by speaker

The general correlates between vowel space and word position interpreted from the above (G1, G2) plots are as follows: For /a/, /i/, and /o/, word final position is correlated to a vowel being centrally articulated. This can help explain some of the centralization scattering (or schwa production) seen in the speakers. It appears that vowels that come at the end of a word are articulated more schwa-like. Additionally, word medial position correlates to high articulation for /i/, or movement away from schwa-like articulations. And as a special case, word final position is found with lower /u/ vowels, possibly adding a more schwa-like centralization effect to this particular vowel. Overall, the general findings from the vowel plots by word position help explain some of the centralization effects seen in the initial vowel plots. This can account for some of the central scatter seen in Figures 1 and 2.

### 3.3 Phonetic Environment

To better test the four vowel phonemic system hypothesis in Tsuut'ina, possible effects of coarticulation are also looked at in the (G1, G2) plots. Since it is hard to imagine that the surrounding phonetic environment does not influence the articulation of the vowels, the preceding and following consonants were transcribed and analyzed for each vowel token. Figures 8-11 below depict the consonant preceding each vowel. The preceding consonant is plotted where the (G1, G2) vowel coordinates are to compare how the vowel space for each vowel shifts in correlation with the preceding consonant. (A “-” indicates that there was no preceding consonant, i.e. the vowel was word-initial.)

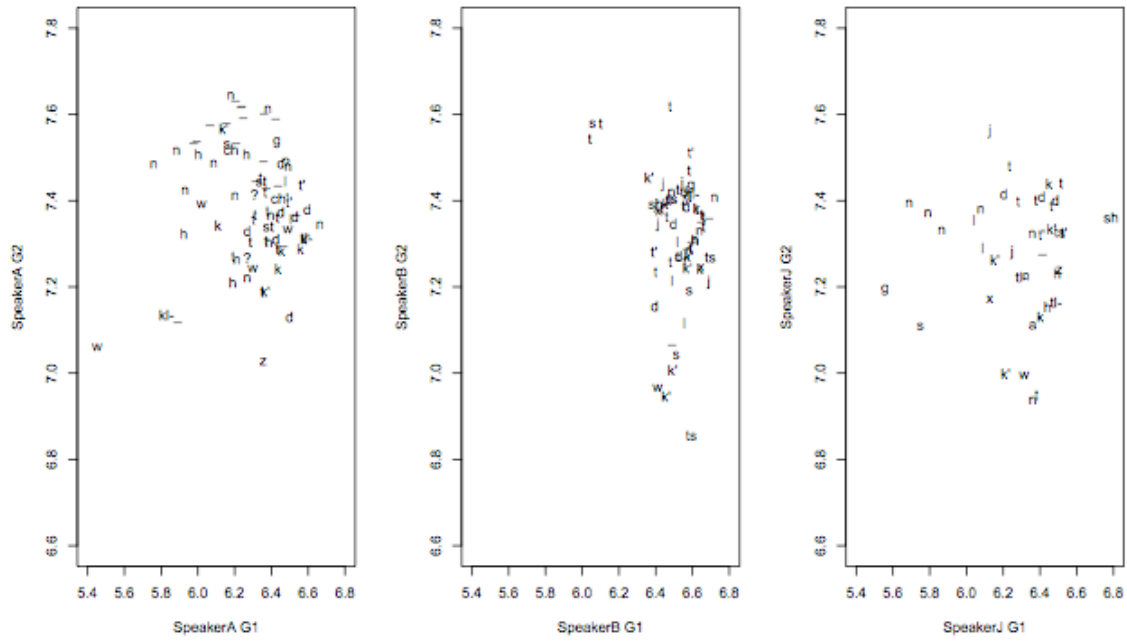


Figure 8 – (G1, G2) for /a/, labeled by preceding consonant, grouped by speaker

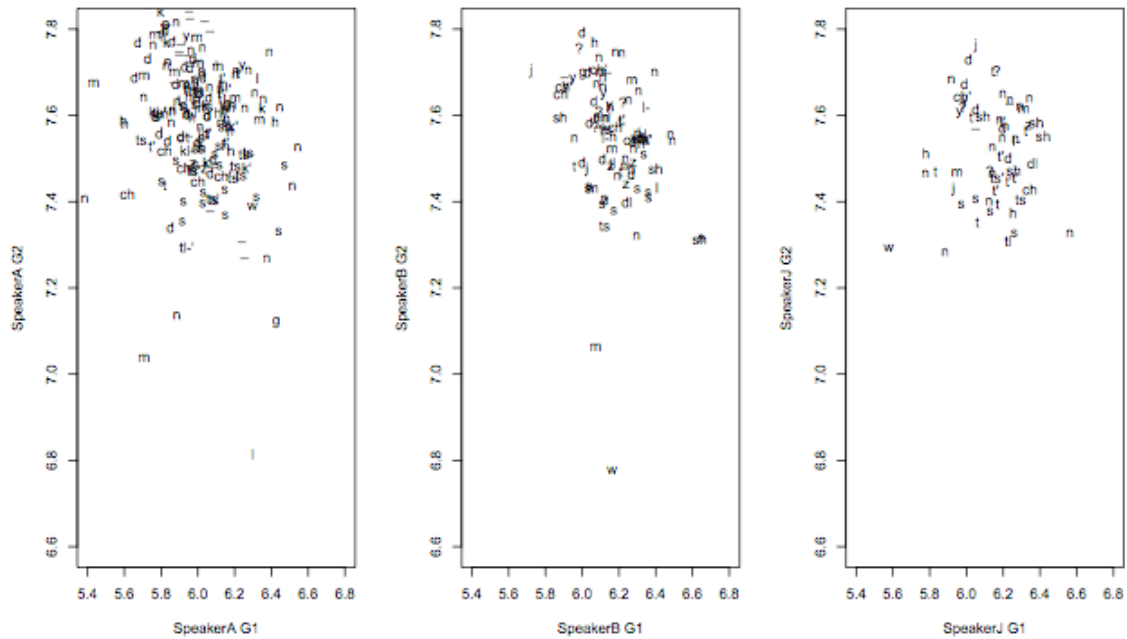


Figure 9 – (G1, G2) for /i/, labeled by preceding consonant, grouped by speaker



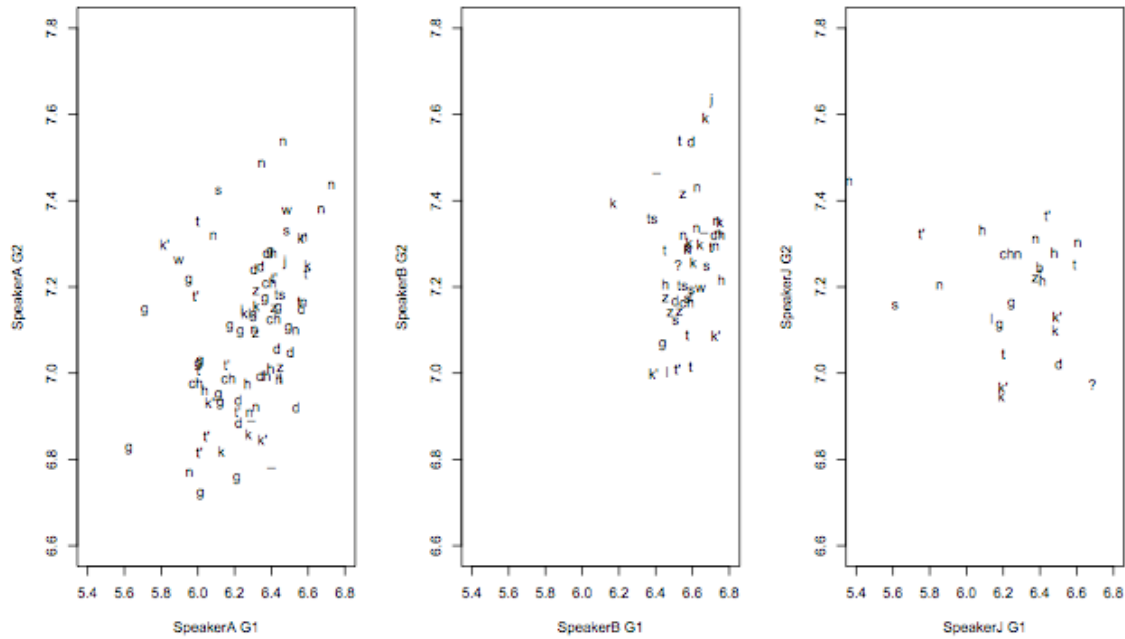


Figure 10 – (G1, G2) for /o/, labeled by preceding consonant, grouped by speaker

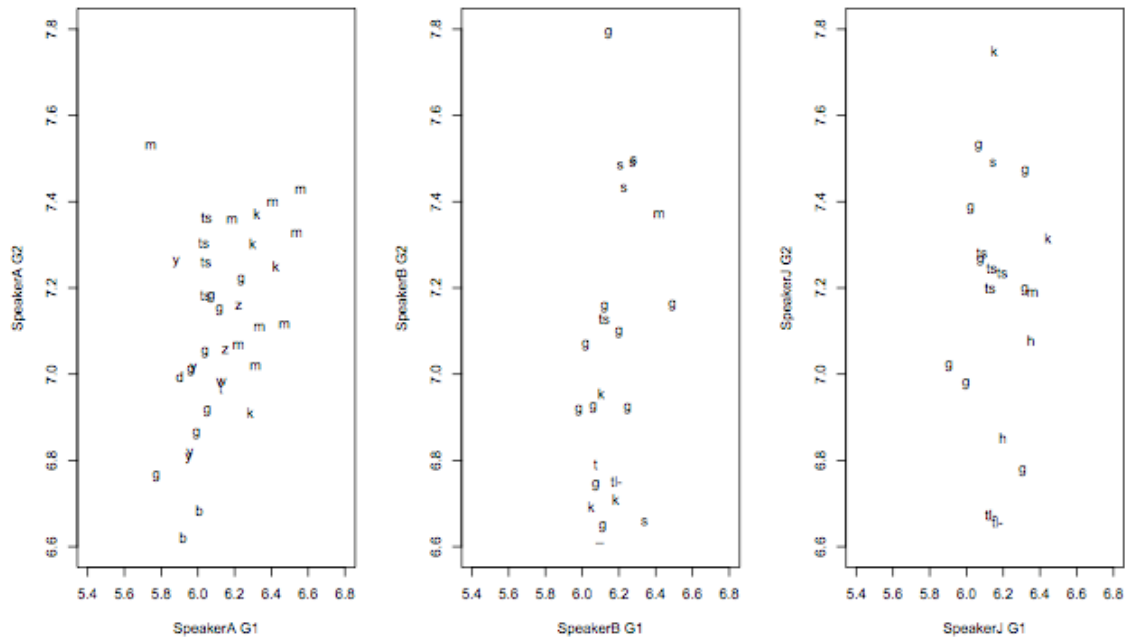


Figure 11 – (G1, G2) for /u/, labeled by preceding consonant, grouped by speaker

The (G1, G2) plots for the preceding consonant yield the following observations: For /a/, the alveolar consonants /n/, /s/, and /t/ as well as the lack of a preceding consonant (denoted on the plots as “-”) seem to group in the frontal areas of the plot. However, the affricates /ts/ and /ch/ as well as back consonants /k/, /g/, and /w/ correlate with more back areas of the vowel space. This is also found in the case of /i/ and /u/ where /-, /m/, /n/, /d/, and /t/ correlate with

frontness and /ts/, /ch/, /tʃ/, /kʃ/ and /w/ correlate with backness. The only vowel to not follow this front/back distinction is /o/, where no correlation could be found. Generally, though, it can be said that more frontal consonants cause phonetic fronting of the vowels, while more back consonants correlate with a sort of backing of the vowels. Here it is evident that the preceding consonant has an effect on the articulation of a vowel in terms of its degree of frontness or backness. To further analyze the phonetic environment surrounding the vowel tokens, figures 12-15 similarly look at the consonant following each vowel.

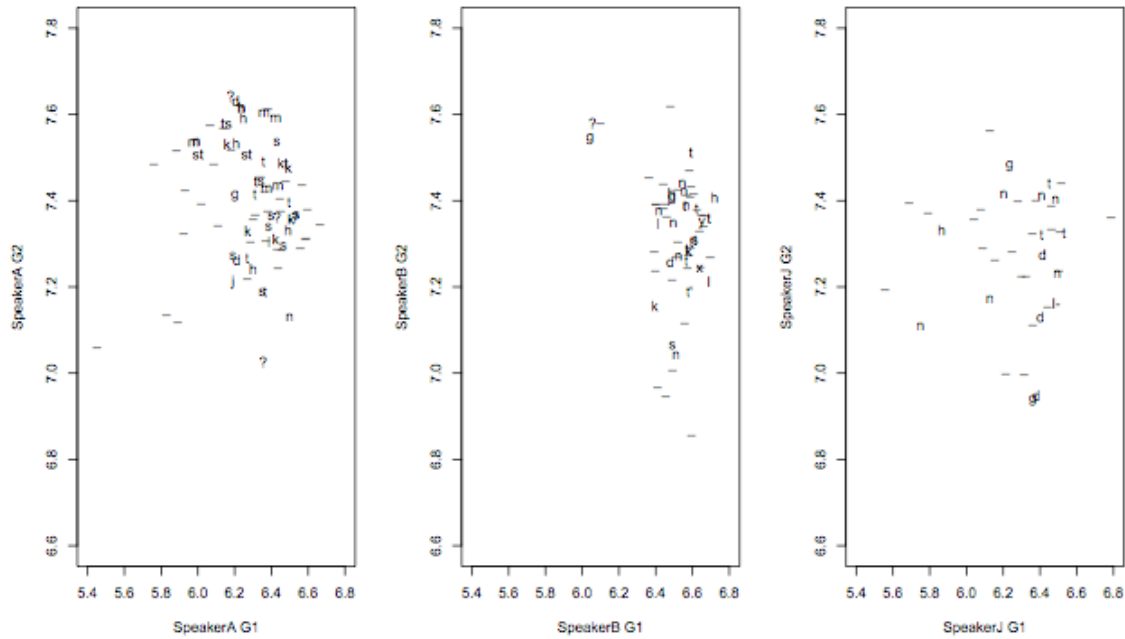


Figure 12 – (G1, G2) for /a/, labeled by following consonant, grouped by speaker

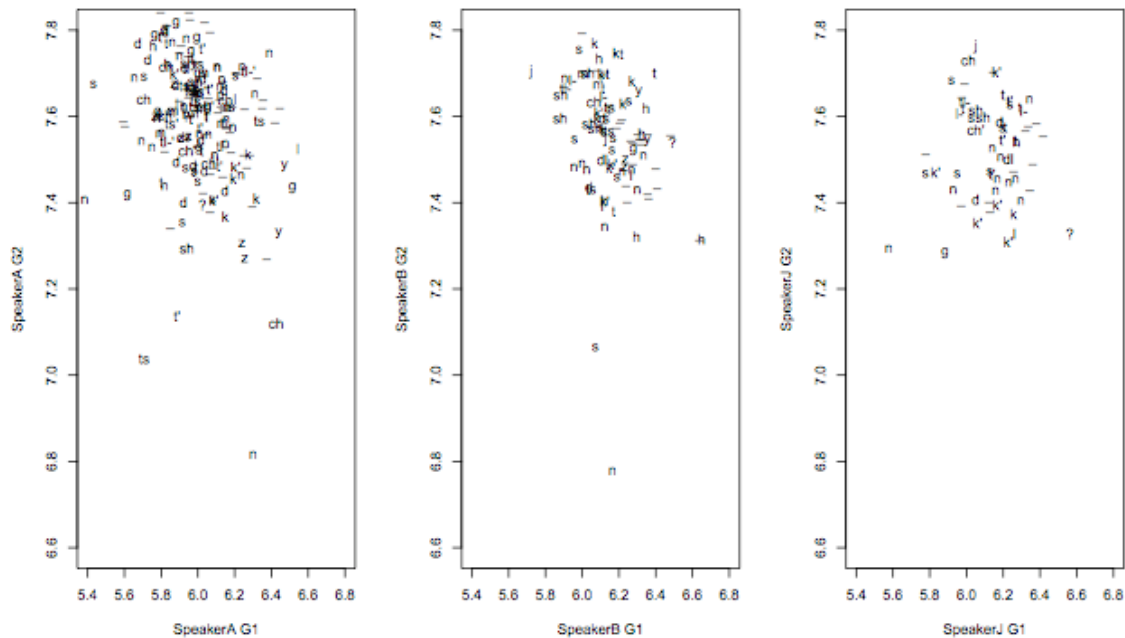


Figure 13 – (G1, G2) for /i/, labeled by following consonant, grouped by speaker

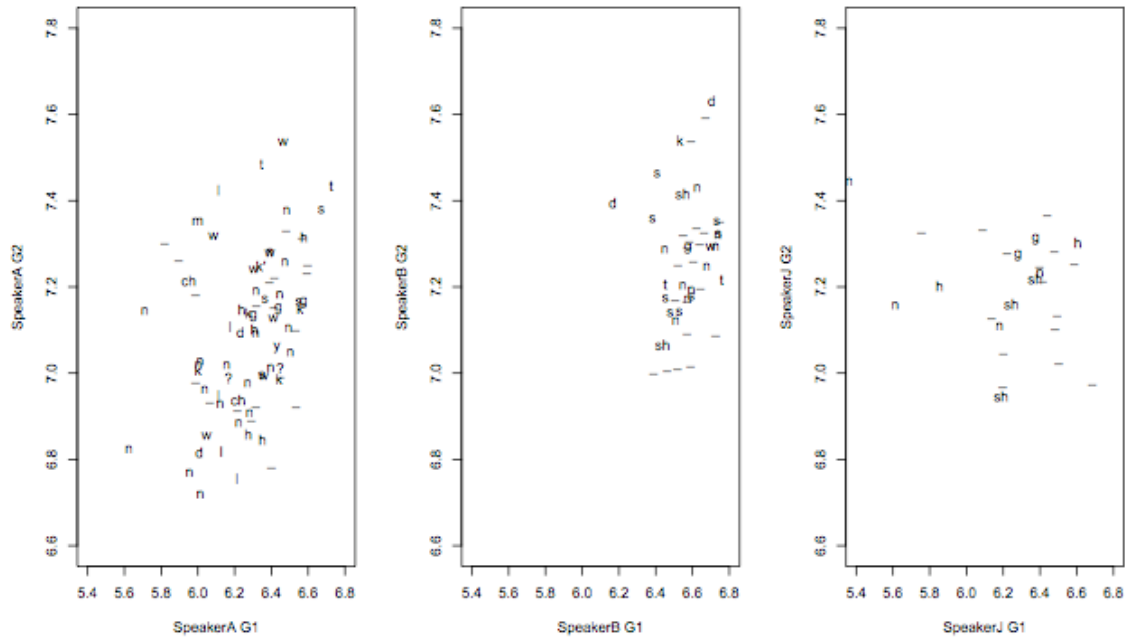


Figure 14 – (G1, G2) for /o/, labeled by following consonant, grouped by speaker

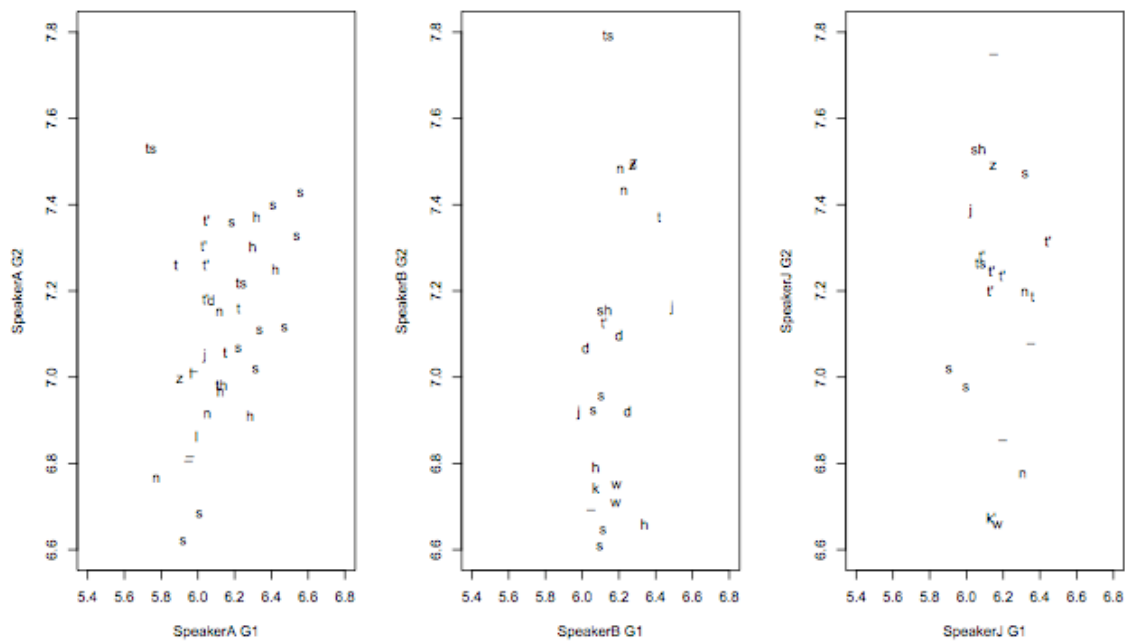


Figure 15 – (G1, G2) for /u/, labeled by following consonant, grouped by speaker

Unlike with the preceding consonant, there does not seem to be any correlation with a vowel's articulation and the following consonant. Vowels, then, seem to be more coarticulated with the preceding consonant, rather than the following one. These findings are perhaps not surprising since the syllable structure of Tsut'ina tends to be more CV, and rarely CVC (e.g.

CV: /go.na.hi/ “talk” versus CVC: /buus/ “cat”) as found by Rice (2000). That is to say, the super-segmental structure of the language itself is arranged so that vowels are to coarticulate with their preceding consonant. This phenomenon, then, can be viewed as more than just a correlation, but as a direct relationship to vowel space.

### 3.4 Duration

As Cook (1971 & 1984) and Li (1930) find duration to be a phonemic characteristic of the Tsut'ina vowels, it is taken under investigation here. Tsut'ina distinguishes between two vowel lengths in its phonemic system: a short length and a long length. While length is used to phonemically distinguish vowels, this section looks at the possibility for length to affect the vowel space. Figures 16-19 show the (G1, G2) plots of each vowel according to their phonemic vowel length.

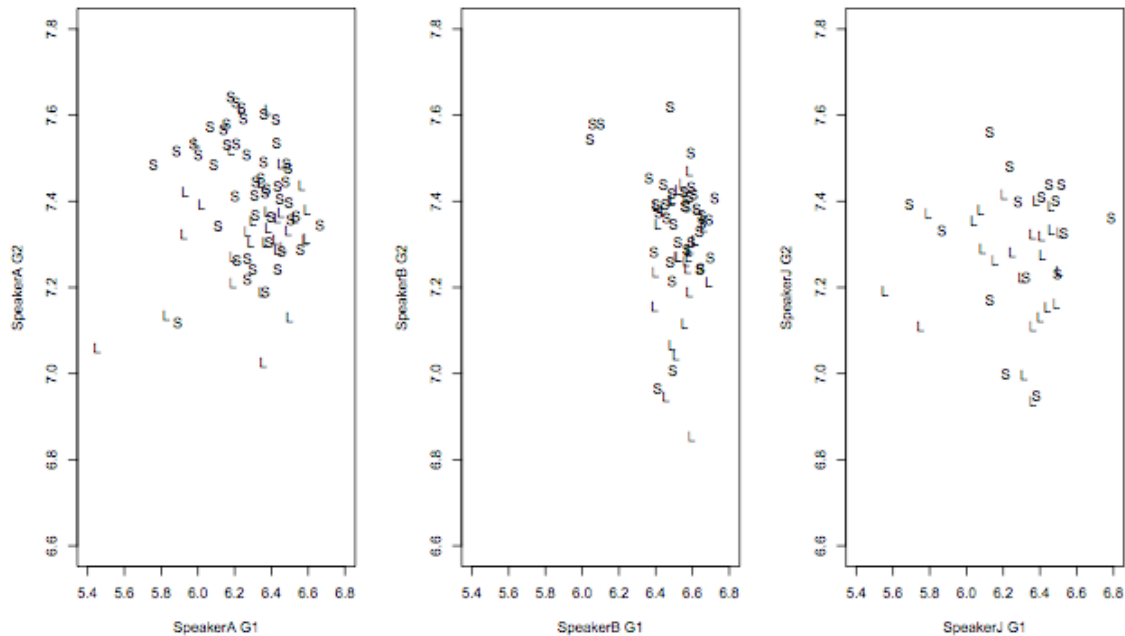


Figure 16 – (G1, G2) for /a/, labeled by length, grouped by speaker

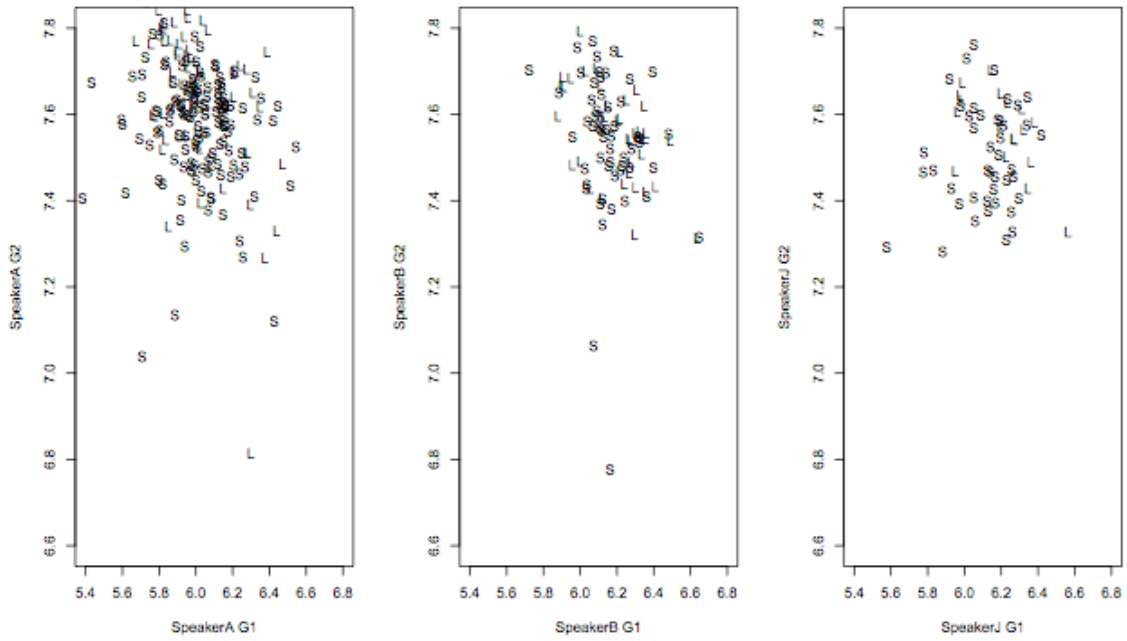


Figure 17 – (G1, G2) for /i/, labeled by length, grouped by speaker

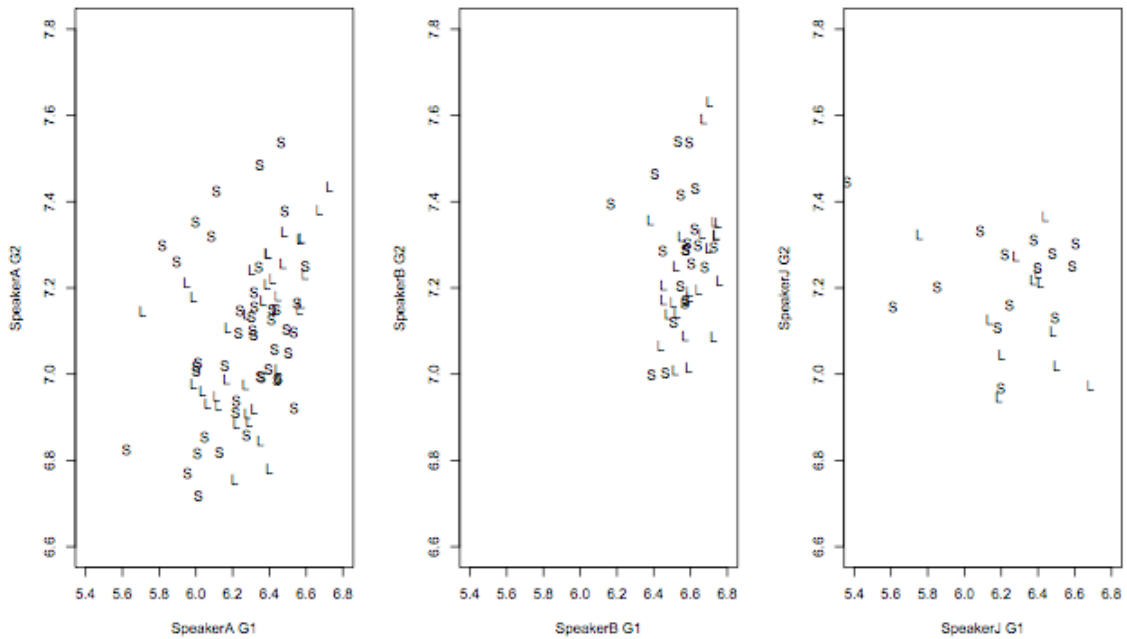


Figure 18 – (G1, G2) for /o/, labeled by length, grouped by speaker

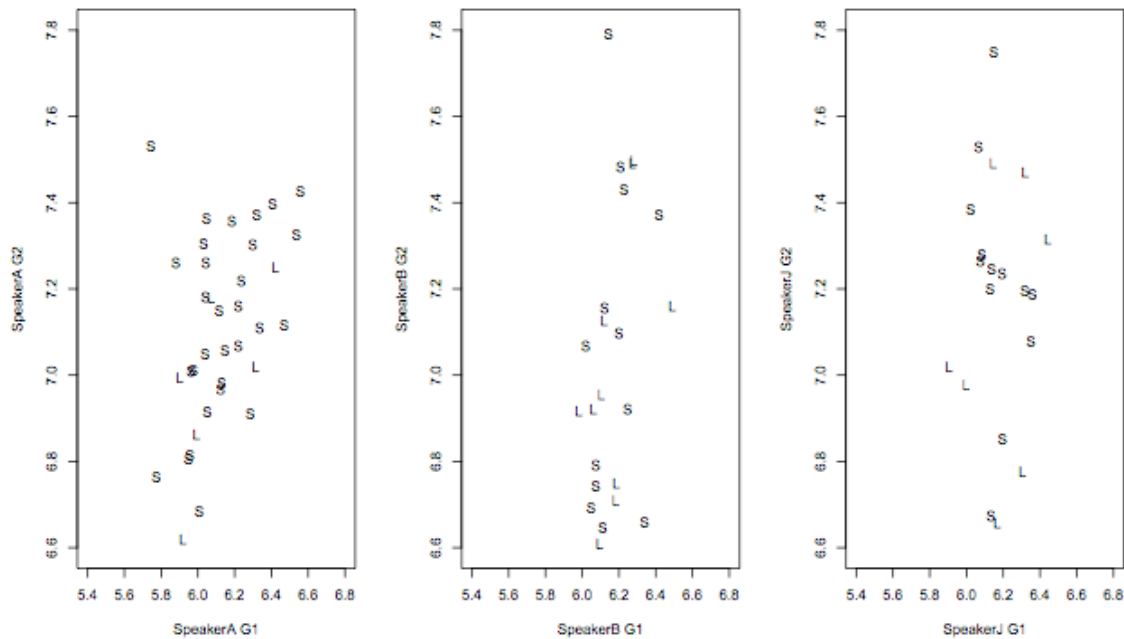


Figure 19 – (G1, G2) for /u/, labeled by length, grouped by speaker

From the (G1, G2) plots, the only strong correlations to be made between length and vowel space are with vowels /a/ and /u/. Both vowels exhibit higher vowel spaces with short lengths, and lower vowel spaces with long lengths. The vowel /o/ also shows correlates with long vowel lengths and low vowel space, but it is not the case that short /o/ vowel lengths correlate with high vowel spaces. There are no correlations to be found with /i/ in terms of length.

### 3.5 Pitch

As first observed by Sapir (1925) and later expanded upon by Li (1930), Cook (1971 & 1984) and Rice (2000), the pitch of a vowel also carries phonemic meaning, making Tsuut'ina a tonal language. The number of tones that Tsuut'ina uses is debated, with distinctions placed from three (Rice 2000) to six (Cook 1971). Speakers of the language generally concur that there are at least three tones. For the purposes of this study, the speakers' consensus of three tones is used and the levels are defined as high (denoted as "H"), mid (denoted as "M"), and low (denoted as "L"). (F0 values that could not be properly measured due to recording quality or vocal characteristic – for example, the use of breathy or murmur voice – are denoted as "-" on the plots below.) Figures 20-23 depict the (G1, G2) vowel spaces according to the tone levels of each vowel.

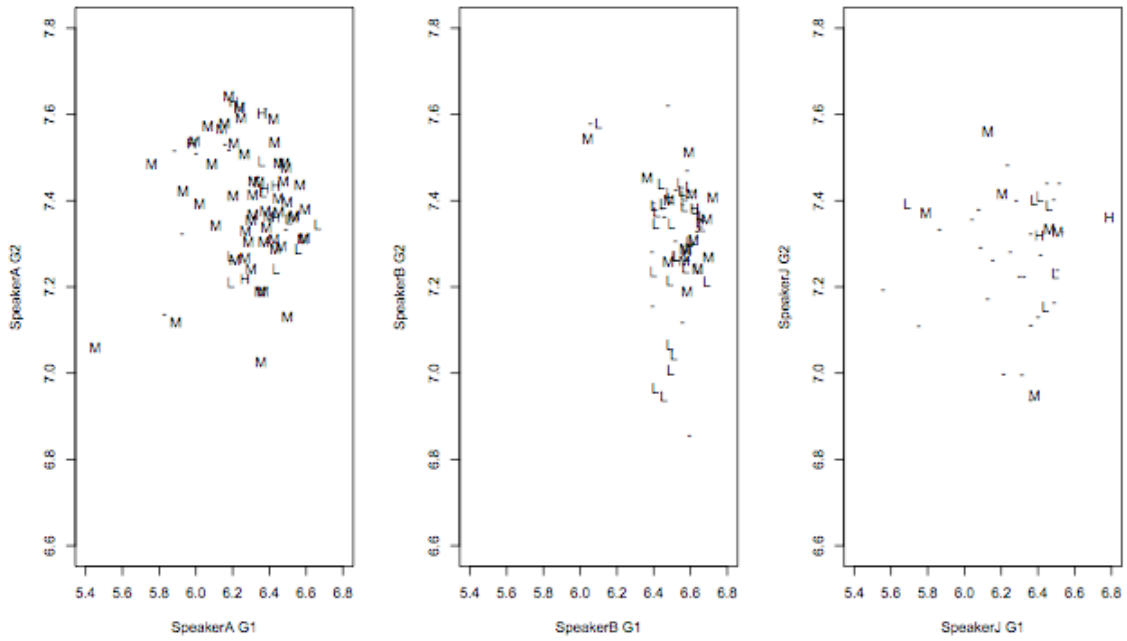


Figure 20 – (G1, G2) for /a/, labeled by length, grouped by speaker

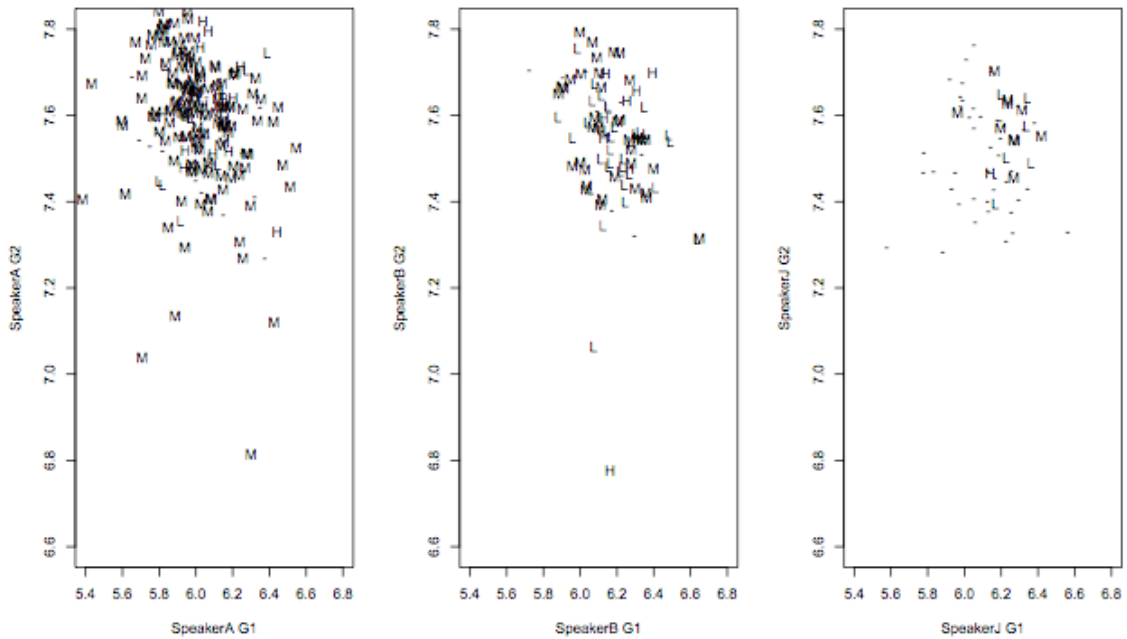


Figure 21 – (G1, G2) for /i/, labeled by length, grouped by speaker

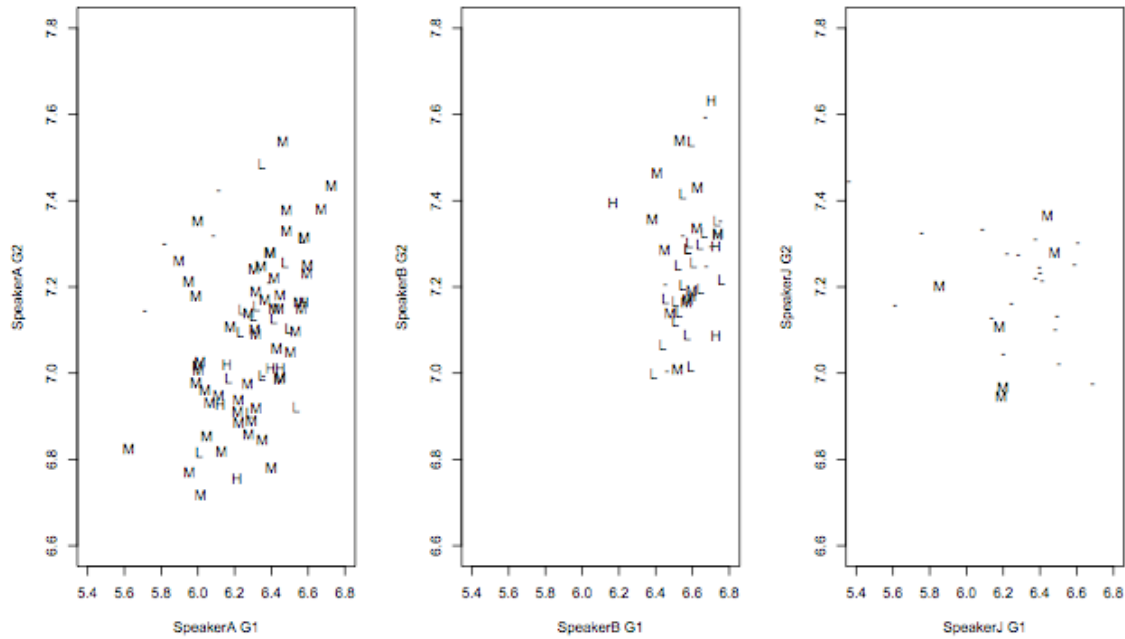


Figure 22 – (G1, G2) for /o/, labeled by length, grouped by speaker

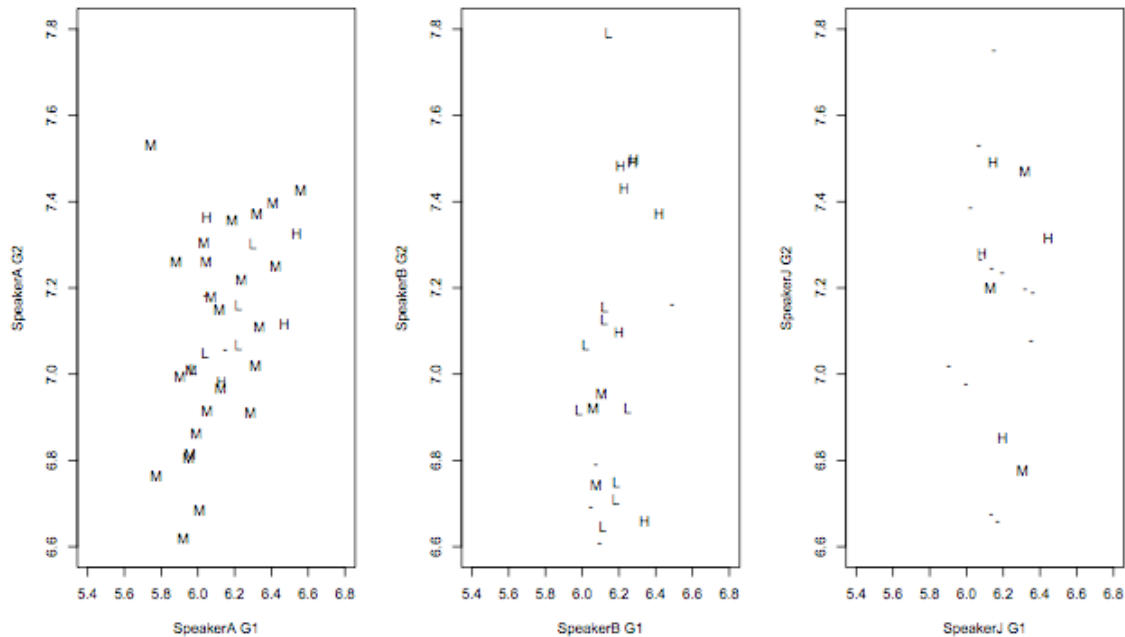


Figure 23 – (G1, G2) for /u/, labeled by length, grouped by speaker

Overall, it seems that Speaker A is the only speaker to exhibit any correlation with tone. The mid tone of Speaker A is used with more scattering of the /a/ and /o/ vowels. This scattering could be interpreted as a centralization effect of pitch for Speaker A. However, no other correlations between pitch, vowels, and speakers are to be seen.



## 4 Discussion and Conclusion

This paper has illustrated that (G1, G2) plotting can show how phonetic and phonological parameters play a role in defining the vowel space for the Tsuut'ina language. First, a vowel's word position can account for most of the centralization and schwa-like productions in the language. Moreover, pitch and tone may account for more of the centralization variance and, perhaps, for the schwa-like productions of the low back vowels seen in Speaker A's vowel space. It does not appear that vowel length has any correlation with vowel space, except in the isolated cases of the /u/ and /a/ vowels, where a short length correlates with frontness and a long length correlates with backness. However, it seems that coarticulation with the preceding consonant is the greatest contributor to the scattering and indistinguishable nature of the Tsuut'ina vowel space. That is, Tsuut'ina vowels are heavily influenced by their surrounding phonetic environment.

Returning to the overarching issue of wholly defining the Tsuut'ina vowel space, there is not enough evidence to support the notion of the language having a four vowel phonemic system. All of the 786 vowel tokens recorded can be accounted for with a revised three vowel phonemic system theory: there are three phonemic vowels – high front /i/, high back /u/, and low /o/ – that undergo phonetic alterations according to word position, coarticulation, pitch and length. This is especially illustrated with an example of coarticulation: It is hypothesized that the low vowel is produced as [a] when it occurs after front consonants, and produced as [o] otherwise. Vowel length, too, is also hypothesized to play a role in what is produced as a low front vowel. Here it can be said that the low vowel is produced as [a] with it is of short length, and as [o] otherwise. While /a/ and /o/ have previously been thought of as separate phonemes, this paper proposes that the two vowels are instead allophones of a single low vowel phoneme, /o/.

Currently, as Tsuut'ina has roughly 40 speakers all over the age of 60, the language is well positioned in the path of extinction. It could be the case that Tsuut'ina had in its history four distinct vowels at one point and, as the language began to die out, the lower two vowels combined into one single vowel. The speakers' plots in Figure 2 each contain evidence of such a phonemic shift. While remnants of four vowels can be seen in Speaker B's plots, Speaker A shows signs of the vowel spaces combining into three larger spaces. Speaker J's vowel space is perhaps an extreme case of language extinction vowel shifting, where not only have /o/ and /a/ combined, but have progressed to combining with /i/ and /u/ so that the only vowel distinction left is between front and back. It could be that speakers of Tsuut'ina are in the process of shifting towards not placing as much importance on vowel distinctions but rely instead on other phonemic characteristics such as length, pitch, and coarticulation. In this case, it is important to explore the vowel space with acoustic phonetic methods and analyze the phonemic inventory according to the phonetic parameters that distinguish it.

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