

An Articulatory and Acoustic Description of Word Initial and Word Medial  
Fricatives and Approximants in Mangetti Dune !Xung

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## **Abstract**

Lingual ultrasound data at 114 fps of 3 speakers' productions of words containing six word initial and word medial fricatives and two approximants are presented for Mangetti Dune !Xung. The midsagittal tongue edge was traced at three frames throughout the consonant and each trace was measured for constriction location and constriction degree. Results show that articulatory strategies vary widely by speaker in the production of these fricatives and approximants, making any claims about a phonetic basis for positional constraints difficult to ascertain. Acoustic measurements were also made for the duration of the fricative and approximant consonants. Many of the acoustic results for duration are similar to those found for English (Jongman et al. (2000)), Modern Standard Arabic (Al-Khairy (2005)), and Gulf Spoken Arabic (Abu-Al-Makarem (2005)). An effect for word was found, and further Tukey post hoc tests revealed significant differences in some expected directions but not all.

**Keywords: fricatives, !Xung, constriction degree, constriction location, duration**

## **Section 1. Introduction**

Mangetti Dune !Xung is a “Khoesan” language in the Kx’a family (Heine & Honken 2010) spoken by approximately 500 speakers in Mangetti Dune village in Namibia. Khoesan is no longer considered a language family (Guldemann & Vossen 2000); however, I use it here as a term that describes click languages that are also both non-Bantu and non-Cushitic. Mangetti Dune !Xung also has a population of speakers in Schmittdrift, South Africa, and it was originally spoken in Angola. Mangetti Dune !Xung is an under-documented language that uses clicks as the primary and most common consonants. As I will show, fricatives are not very common in the language overall, occurring in only 11% of the 974 words that have been recorded in the Mangetti Dune !Xung word database (Augumes et al. 2010), and approximants are equally as uncommon as fricatives (occurring in 10% of the words in the database).

In this paper, I seek to increase the documented information on Mangetti Dune !Xung by describing the language’s fricative and approximant inventory, their positions in known words, and how these sounds pattern phonologically with different vowels. An experiment has also been performed to explore phonetic differences in word position on fricatives and approximants in Mangetti Dune !Xung in order to assess if a phonetic basis exists for positional constraints on fricatives and approximants similar to the BVC in Khoekhoe, another Khoesan language. In Mangetti Dune !Xung, stronger fricatives, such as stridents and gutturals seem to primarily occur in word initial position and other, weaker, consonants occur primarily in word medial position. In this aim, I measured acoustic and articulatory attributes that have, in previous research, signaled place and manner of articulation. In this paper, I will also describe how these variables contribute

to maintaining contrasts across different phonemes when they occur in similar positional and vowel contexts.

Iskarous et al. (2012) reported that in Navajo, the word initial voiceless velar fricative has variants that are pronounced as /ç/, /ɣ/ and /w/, so although my main interest in this paper regards fricatives, I also include approximants in my study in order to explore the possibility that Mangetti Dune !Xung could show similar fricative to approximant variation.

My predominant research questions are:

- 1) Is there a phonetic basis for positional constraints on fricatives in Mangetti Dune !Xung? If so, what are they?
- 2) Is there fricative - approximant variation, similar to what was found in Navajo in Iskarous et al (2012)?

I explore these questions in detail by describing articulatory and acoustic differences between fricatives and approximants in word initial versus word medial position. Articulatorily, overall tongue shape will be examined as well as constriction location and constriction degree. Acoustically, duration of the consonant will be analyzed.

Upon beginning the experiment, fricative - approximant variation was hypothesized, primarily in word medial position due to coarticulatory processes with the preceding and following vowels, but also in word initial position due to the results found in Navajo (Iskarous et al. 2012). Also, it was hypothesized that one or more of the articulatory or acoustic measurements could suggest a phonetic basis for the patterning of certain fricatives and approximants in Mangetti Dune !Xung occurring in both word initial and word medial position versus other fricatives and approximants occurring primarily in word medial position.

## **Section 2. Literature Review**

### **Section 2.1 Surveying the Inventories of Related Languages**

Brugman (2009) discussed the phoneme inventory of Khoekhoe. Another Khoesian language, Khoekhoe is spoken by approximately 250,000 people within Namibia, South Africa and Botswana. Khoekhoe is reported as having three fricatives: [s], [x] and [h], one approximant, a dental flap, and a five vowel system: /i/, /e/, /a/, /o/, and /u/. Vowels can be further distinguished by nasalization, and there is also the formation of diphthongs. Brugman also reported variation for [x]. In Khoekhoe, [x] varies in production from a strong velar fricative to a uvular fricative. She did not, however, report on which vowel context the variability occurs in, as the subject of her dissertation was focused more on clicks in Khoekhoe.

Ju|hoansi, a Kx'a language spoken by approximately 30,000 people in northeastern Namibia and 5,000 people in Botswana, has seven fricatives: /f/, /s/, /z/, /ʃ/, /ʒ/, /χ/ and /ħ/ (Miller 2003). Miller (2003) also reports that a five vowel system exists, containing /i/, /e/, /a/, /o/, and /u/, with additional variation based on the formation of diphthongs, and also pharyngealization. Note that Ju|hoansi makes use of a voicing contrast in four of its seven fricative phonemes: /s/ - /z/ and /ʃ/ - /ʒ/. Fricatives, in general, are of low frequency in Ju|hoansi (by comparison to click consonants, which are the predominant consonants), and Miller (2007) reported that /f/ has the lowest frequency of all the known fricatives.

N|uu, in the Tuu language family that has typological similarities to the Kx'a language family, has six fricatives: /β/, /f/, /s/, /z/, /χ/, and /ħ/. Miller, in a currently unpublished paper on N|uu, reported that N|uu has a five vowel system that is the same as Ju|hoansi, with the addition of diphthongs, nasalization, epiglottalization, and nasal-epiglottalization to provide contrast

within the vowel system. Similarly to Ju|hoansi, /f/ is rare, and /s/ and /z/ contrast in a voicing distinction. In N|uu, only sibilant fricatives occupy word initial position, and non-sibilant fricatives occur in word medial position. In word initial position, the fricatives will be in “strong” position and be more obstruent-like. However, in word medial position, fricatives will be intervocalic (due to a basic root structure of CVCV). Miller describes this process as sibilants being represented as prosodically “strong”, or more like obstruents, and non-sibilants being prosodically “weak”, or more like sonorants. Although Miller makes a few of her own modifications, overall, her analysis of N|uu fricative behavior follows Browman & Goldstein’s (1989) theory of Articulatory Phonology, arguing for a straightforward mapping between phonetics and phonology where contrasts between phonemes are described in terms of the interactions of the movements of several articulators at once.

The wide range of place of articulation across Mangetti Dune !Xung fricatives and approximants (/β/, /v/, /s/, /h/, /fi/, /χ/, /l/ and /w/) means that I will not be able to only use ultrasound to investigate the phonetic basis for positional constraints. Ultrasound is only able to clearly image the soft tissue, so the jaw bone and teeth create a shadow where lip movement in bilabial and labiodental consonants may have been able to be seen otherwise. For this reason, I also included duration to provide acoustic data on place in comparison to Arabic and English fricatives.

## Section 2.2 Measurements: Duration, Constriction Degree and Constriction Location

Al-Khairy (2005) investigated durational cues of fricatives in Modern Standard Arabic (MSA) in his doctoral dissertation. Al-Khairy showed that sibilants in word initial position in

MSA were longer than non-sibilants in word initial position, and voiceless fricatives were longer than voiced.

Abu-Al-Makarem (2005) analyzed eight voiceless fricatives in word initial position in Gulf Spoken Arabic and found a main effect of fricative type on duration. Of the eight fricatives analyzed in Abu-Al-Makarem's study, only three are represented in this study: /s/, /χ/, and /h/. Of these three fricatives, /s/ had the longest mean duration (148.0 ms) followed by /χ/ (135.6 ms) and then by /h/ (92.1 ms). Fricative duration for /h/ was also found, in Tukey post hoc comparisons, to be significantly shorter than all other fricatives tested.

Jongman et al. (2000) studied eight English fricatives, all in word initial position. A four way ANOVA for duration for place, voicing, vowel and gender found a main effect for place. Bonferroni post hoc tests found a significant difference for sibilant vs. non-sibilant, and once adjusted for normalized duration rather than absolute duration, only the difference between labiodental and dental fricatives was found to not be significant. A main effect for voicing was also found for normalized duration. Bonferroni post hoc tests also found decreased duration corresponding to decreased vowel height.

Shadle et al. (2008) reported on MRI data for the fricatives of five native speakers of English (/f/, /v/, /θ/, /ð/, /s/, /z/, /ʃ/ and /ʒ/). Magnetic Resonance imaging is able to describe the entire shape of the tongue including tongue root, tongue body, and tongue tip as well as the size of the sublingual cavity. Tongue root advancement/retraction, the effects of vowel context on the shape of midsagittal contours, and constriction location were described.

Tongue shape for [v] was expected to be that of the surrounding vowel contexts; however, this tongue shape was found for only one speaker. Other speakers used a high back

constriction location similar to [u] or a high front position like that of [i] regardless of surrounding vowels. Results of comparisons between [f] and [v] showed that the voiced labiodental fricative had a farther forward tongue placement than the voiceless labiodental fricative but that there was a lot of variation in tongue position for [f].

Tongue shape for [s] was described as having a concavity behind the constriction location that is affected by vowel context as well as showing advanced tongue root for the voiced fricative compared to the voiceless fricative. Constriction location was described as being robust against coarticulation.

Iskarous et al. (2012) described word initial [x] in Navajo as having approximant-like variation in differing vowel contexts. The results showed that, before [a], the constriction degree was less than before [o], and the constriction location was farther back in the mouth. Results indicating approximant-like variation for [x] were surprising due to being unexpected according to Steriade's (1994) description of stem-initial position being "strong," and thus, expected to demonstrate less variability of this kind.

Fougeron & Keating (1997) described articulatory and acoustic strengthening over four prosodic domains. The phonological word, intermediate phrase, intonational phrase and utterance were all considered. Using electropalatographic methods measuring linguopalatal contact and duration, domain initial consonants were determined to be stronger than domain medial or domain final consonants. Articulatory differences were found to be more extreme (more and longer linguopalatal contact) around domain boundaries, increasing contrast between consonants and the surrounding vowels. However, at the word level, variation was present in the patterns amongst speakers. One speaker showed no variation amongst word initial, word medial or word

final consonants, another speaker demonstrated more strengthening of word initial consonants over word medial consonants but not over word final consonants, and the third speaker's word initial consonants were stronger in word initial position than either of the other positions.

Consonants at domain boundaries also demonstrated a lengthened duration.

### Section 2.3 The Fricative, Approximant, and Vowel Phoneme Inventory

The words in my stimuli list were chosen from a database of 974 words that have been documented in Mangetti Dune !Xung. It should be noted here that the database was transcribed according to Dickens (1994) orthography of Ju|hoansi, and the transcriptions were checked with native speakers who were taught to write in a local school and have been given limited amounts of training in transcription. One of the transcribers is a native speaker and was taught to write Mangetti Dune !Xung by two Ju|hoansi transcribers through an Endangered Languages Documentation Project.

According to the database, 7 fricative phonemes and 3 approximant phonemes exist. Unlike Khoekhoe, which only uses 3 fricatives, Mangetti Dune !Xung has a fairly large inventory of fricatives, with 8 documented fricatives. Mangetti Dune !Xung uses a distinction of place rather than voicing with the exception of the glottal fricatives, /h/ and /ɦ/. Unlike Ju|hoansi and N|uu, there is not a voicing contrast in the alveolar place of articulation.

Table 1 demonstrates all of the currently documented fricatives and approximants in Mangetti Dune !Xung by place of articulation.

	Bilabial	Labiodental	Alveolar	Postalveolar	Palatal	Uvular	Glottal
<b>Fricative</b>	β	v	s	ʃ		χ	h    ɦ
<b>Approximant</b>	w		l		j		

Table 1. The fricative and approximant inventory of Mangetti Dune !Xung based on the 974 word database (Augumes et al.).

Figure 1 shows the frequencies for the fricatives and approximants in the 974 word database. /s/ is the most common fricative, followed closely by /β/. /ʒ/ only occurs once, and /h/ has only 3 tokens. Of the approximants, /l/ clearly has a larger number of tokens than either /w/ or /j/.

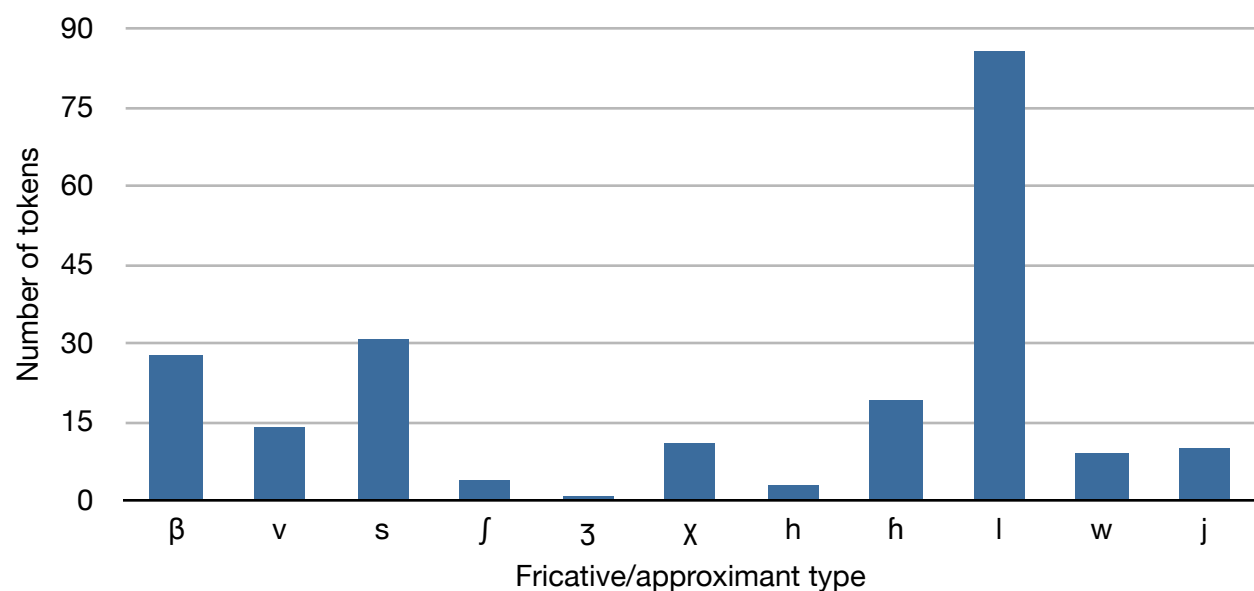


Figure 1. Token frequencies of fricatives and approximants in the Mangetti Dune !Xung database (Augumes et al. 2010).

The database records 11 vowels for Mangetti Dune !Xung. This is substantially larger than any of the other languages surveyed in this paper, and, as stated previously, is based primarily on phonetic transcription. It is unclear at this point if all of the documented vowels are actually phonemes. Table 2 shows all of the currently documented vowels in the language. Note

that the only open vowel is [ɑ], that the front and central vowels are all unrounded, and the back vowels, with the exception of [ɑ], are all rounded.

	Front		Central		Back	
	Unrounded	Rounded	Unrounded	Rounded	Unrounded	Rounded
<b>Close</b>	i		ɨ			u
<b>Near-close</b>	ɪ					ʊ
<b>Close-Mid</b>	e					o
<b>Mid</b>			ə			
<b>Open-Mid</b>	ɛ					ɔ
<b>Near-open</b>						
<b>Open</b>					ɑ	

Table 2. The vowel inventory of Mangetti Dune !Xung based on the 974 word database (Augumes et al.).

Mangetti Dune !Xung has 13 diphthongs demonstrated in the database. The diphthongs begin either with a back or central vowel, and the second vowel varies in height, either remaining a back vowel or moving forward, for back vowels, or, for where the first vowel is a central vowel, forward or back. Mangetti Dune !Xung also has been transcribed as having contrastive breathy, nasalized, epiglottalized, nasalized-epiglottalized, breathy-nasalized, and breathy-epiglottalized vowel phonemes. Table 3 demonstrates all of the known diphthongs in Mangetti Dune !Xung, organized according to the first vowel.

<b>Back, Low</b>	<b>Back, Close-Mid</b>	<b>Back, High</b>	<b>Central, Mid</b>
ɑo	oɑ	uɑ	əu
ɑu	oe	ue	əi
ɑe	oi (1x)	ui	
ɑi			

Table 3. The diphthong inventory of Mangetti Dune !Xung based on the 974 word database (Augumes et al.), organized by the first vowel in the pair.

## Section 2.4 Describing the Word Positions of Fricatives and Approximants

Words in Mangetti Dune !Xung have CVV, CVCV, or CVCVCV structure. According to Dr. Miller (personal communication, April 19, 2013), most, if not all of the CVCVCV words are loan words from Afrikaans or another contact language.

Table 4 shows that /β/, /h/ and /l/ do not occur in word initial position. /ʃ/ does not occur in word medial position. /v/ and /w/ occur in both word initial and word medial position; however, they have more tokens in word medial position than in word initial position. Additionally, /s/, /χ/, /ɦ/, and /j/ have tokens in both positions but more tokens in word initial position. This difference is particularly noticeable for /s/ and /χ/.

Phoneme	Word Initial	Word Medial	Total Number of Tokens
/β/	0	28	28
/v/	3	11	14
/s/	25	6	31
/ʃ/	4	0	4
/χ/	10	2	11
/h/	0	3	3
/ɦ/	11	8	19
/l/	0	86	86
/w/	2	7	9
/j/	5	3	8

Table 4. Fricatives and approximants by word initial or word medial placement and total number of tokens.

## Section 2.5 Fricatives and Approximants in Vowel Contexts

Due to there being 2 word positions, 8 fricatives, 11 monophthongs, and 13 diphthongs, I could not think of any chart that would easily and clearly display all consonant and vowel pairings. So, I will describe the most salient patterns here instead. [ɑ], [o], and [u], all back

vowels, are the most common vowels found with fricatives, occurring in more than half of the tokens. [a] is the most common vowel to pattern with fricatives in the database, and it is also one of the most common vowels found in the database in general. 25% of the tokens in the database that contain a word initial fricative have an [a] vowel following the fricative. 77% of the tokens that contain a word medial fricative are either preceded or followed by an [a] vowel - in 34% of the tokens, the [a] vowel is before the target fricative, and in 43% of the tokens, the [a] vowel is after the target fricative. /χ/, has a vowel pattern unlike all of the other fricatives. In the currently documented words of Mangetti Dune !Xung, /χ/ patterns with [ə] in 55% of the tokens.

The approximants also primarily pattern with [a], [o], and [u]. /l/ does occur with every vowel recorded in the database; however, it most frequently occurs with [a], [o] and [u].

### **Section 3. Methods**

#### **Section 3.1 The Stimulus List**

The stimulus list was created with several factors in mind. Firstly, in a database of less than 1,000 words, it is extremely difficult to find minimal pairs. Also, it is a property of the language as a whole to create contrast by using a large consonant and vowel inventory rather than by utilizing minimal pair words. Thus, in putting together the stimulus list, I chose to consider surrounding vowel context and syllable count rather than attempting to find only minimal pairs. The length of the stimulus list is limited by restrictions such as how long a subject may wear the headset that holds the ultrasound probe and head correction materials, and Miller and Finch (2011) suggested limiting each session to several takes of 6-8 words. A participant may have several sessions per day.

Approximately two weeks were spent in Namibia altogether and we visited several villages, and our time in Mangetti Dune was about 5 days. The possible recording time was limited by availability of electricity (power was turned off at regular intervals throughout the day) and hard drive space on the ultrasound machine. My stimulus list was limited to 24 words, working with 6 speakers working 2 takes of 12 words per session, two to three sessions per day, with data being captured over 5 days. Full sets of data (4 takes of 24 words) were recorded for 5 of the speakers; the 6th speaker has only two takes of words 12-24. However, the time intensive nature of the methodology limited the amount of data that could be thoroughly and accurately analyzed, so rather than reporting results for 6 speakers, only 3 speakers are represented here, 2 female (DM and IK) and 1 male (JF).

Also, the first 12 words consist of each of the known fricatives and approximants in the [a] context, with the exception of [j]. [v], [s], [ʃ], [χ] and [w] occur in word initial position before [a], and [β], [v], [s], [χ], [h], [ʃ], [w], and [l] occur in word medial position before [a]. I attempted to control for possible effects of the preceding vowel by choosing words that also have an [a] vowel preceding the target sound; however, the closest match to this context for a word medial [w] has a diphthong [ao] preceding the target sound. Each of the word medial fricatives and approximants are the first phones in the second syllable of the word. One word medial fricative is preceded by the diphthong [oa] in the word [koasa], ‘to help,’ and one word medial approximant is preceded by the diphthong [ao] in [glaowa], ‘to put on shoes, to put something inside.’ Word medial [β] and [v] are preceded by long [a] vowels.

The second 12 words were selected to represent each fricative and approximant in a word initial context followed by [i], [o] and [u]. I had originally hoped to include analysis of fricative

and approximant variation from this second set of 12 words in my thesis; however, due to time constraints, these data will need to be analyzed at a later date.

Tables 5 and 6 present the stimulus lists in table form to display the variation in place and vowel context. Note that the data presented in the results section will only include the 12 words in the [a] context (5 word initial, 8 word medial, one word, [χαχα], ‘old man,’ has both initial and medial position). Also note that, although [j] is one of the approximants utilized by Mangetti Dune !Xung, its nature as a glide made it less likely to be able to be compared to relatively stable fricatives or approximants. As a focus of this study is to compare possible fricative and approximant variation, when the stimulus list was narrowed down, [j] was not included in the list.

Word-Initial						
	/χ/	/s/	/ʃ/	/h/	/v/	/w/
α	χàχà, ‘old man’	sà’á, ‘hear, understand’	-----	hǎ, ‘he/she’	vàngá, ‘first’	wàná, ‘find, get something that was lost’
o	χóá, ‘to rub’	sóá, ‘lungs’	ʃóán, ‘sharpen’	hǒè, ‘come!’		
u	χúnú, ‘corrode, chip away at’	sùlá, ‘arrow’	ʃùlá, ‘arrow’	hǔlǐ, ‘stir’		
i	-----	síví, ‘to open’	ʃíí, ‘laugh’	hǐlǎ, ‘those’		

Table 5. Word initial stimuli list. Phonemes by vowel context with Mangetti Dune !Xung word in IPA followed by ‘English translation.’

Word-Medial								
	/χ/	/s/	/h/	/h/	/β/	/v/	/l/	/w/
o_a								gllàòwá, 'put on shoes, to put inside somethin g'
a_a	χàχà, 'old man'	kòàsá, 'to help'	tsǎ́hàʔ, 'pour'	n!àhà, 'belt'	g#àáβá, 'win	g#à'ává, 'enter'	!àlà, 'poison, spider'	

Table 6. Word medial stimuli list. Phonemes by vowel context with Mangetti Dune !Xung word in IPA followed by 'English translation.'

### Section 3.2 Data Collection

The data were collected in a Mangetti Dune !Xung speaking village in northeastern Namibia. Data from 6 speakers, 3 males and 3 females, were collected. Dr. Bonny Sands indicated (personal communication, April 12, 2013) that female speakers tend to have a more /s/ like pronunciation of words documented with /s/ or /ʃ/, and that male speakers tend to have a more /ʃ/ like pronunciation. In order to account for any anticipated gender based variation, I chose as even a gender distribution amongst my native speaker consultants as possible. However, I would like to note that during recording, it seemed as if variation existed on a lexical basis (ie, the word [ʃii] was also pronounced as [tʃii] and [sii], but [sa'a] was always [sa'a], never [tʃa'a] or [ʃa'a]), and seemed to reflect a speaker preference, and so was not always necessarily a gender issue.

The methodology of the data collection followed the CHAUSA (Corrected High Frame Rate Anchored Ultrasound with Software Alignment) method, described by Miller and Finch (2011). Three main data collection machines were used: a GE LogiqE ultrasound machine, a

Prosilica GE 680 C high frame rate video camera, and a Shure F23 battery operated preamp with a Shure SM10A head mounted microphone. The three data signals were connected to the Tri-Modal 3-ms Pulse Generator which generated a 3-ms pulse of audio from a buzzer near the preamp, 3ms of a burst of light that was picked up in the ultrasound video, and 3-ms burst of light in a small brightness light emitting diode (LED) for use in daylight that was then recorded by the three machines at regular intervals throughout each take (Miller and Finch 2011).

The speaker wore an ultrasound stabilization headset created by Articulate Instruments (2008) which had the ultrasound, microphone, and LED light attached to it. Attached to the speaker's head via strapped-on sunglasses and to the headset are two rods that are used to track head movement when recorded by the high frame rate head video, following the Palatoglossatron method described by Mielke et al (2005).

The ultrasound recorded the tongue movement at 114 fps along the midsagittal axis, the head video recorded the movement of the two rods as well as the burst of light from the LED used in the tri-modal system, and the acoustic data were recorded via the headset mounted microphone into the preamp.

At the beginning of each recording session, a swallow is recorded. This swallow is recorded in order to illuminate the shape of the palate, and followed the methodology of Epstein & Stone (2005). The recording of the swallow enables imaging of the palate relative to the exact placement of the ultrasound probe so that later spatial alignment of the tongue trace to the palate is enabled.

The head video was recorded directly onto a data collection laptop into Prostream software. The ultrasound data was stored on the ultrasound machine until it could be removed

with the DICOM transfer protocol into Digital Jacket software, a Dicom server. Miller and Finch (2011) reported that the DICOM transfer protocol enables high frame rate alignment ( $\pm .5$  ms), avoiding spatio-temporal inaccuracies that are common amongst most ultrasound export practices. The acoustic data were recorded onto a Marantz Professional PMD671 Digital Audio Recorder and saved as a .wav file that was later segmented into files representing three repetitions of each target word set in the frame sentence, [siŋ !o ke \_\_, kə dʒala], ‘I said \_\_, it was good’.

Once we returned to the United States, the ultrasound data were exported via DICOM into Digital Jacket software and exported as high frame rate .avi files. The head video files were also then exported out of Prostream as high frame rate .avi files.

In Adobe Premiere Pro, the data were mixed and aligned via the tri-modal US light, audio buzzer, and LED light that was captured in the head video. The final, aligned data were then exported from Adobe Premiere Pro as an .avi file.

Two more steps were necessary before the data could be traced. First, the beginning and end of the fricatives and approximants were annotated in a text grid in Praat (Boersma 2013) and run through a Praat script that identified video frame numbers to look at once the tracing began.

Secondly, a MATLAB script was run on the .avi to create a series of numbered .jpgs.

The .jpgs were then imported to a Palatoglossatron software (Mielke et al., 2005) project, the frames to begin tracing were identified from the output of the Praat script, and the frames of interest were traced. Clicks, which this method has primarily been created for, require 5 traces to accurately describe the shape of the tongue in each phase of the click production. However, fricatives and approximants are less articulatorily complex, and I estimated that only three

frames were necessary: one at the beginning of the frication (the first frame that shows a clear constriction), one at the end (the frame before the offset of the fricative), and one in the middle, as determined by subtracting the first frame number from the last frame number and dividing by two, as done for the uvular fricative by Miller (2012). The duration of the target sounds vary, so in some cases, the three traces are three consecutive frames (ie, [w], which has a duration of 3-5 frames), and in other cases (ie, [s], which varies from about 10-15 frames), the traces are separated by several frames.

In Palatoglossatron (Mielke et al. 2005) and an add-on program for Palatoglossatron called Peterotron, head movement correction techniques were performed which enabled alignment of the tongue traces to the palate within 1 mm accuracy. The traces were then plotted using R software (R Development Core Team 2013) where they were compared. Figure 2 presents a final plot, showing the palate (black), one alveolar click trace (from the frame just before the release, in red), and three traces within the fricative, the first frame in the fricative, the last frame in the fricative, and the frame mathematically halfway between the first and last frames.

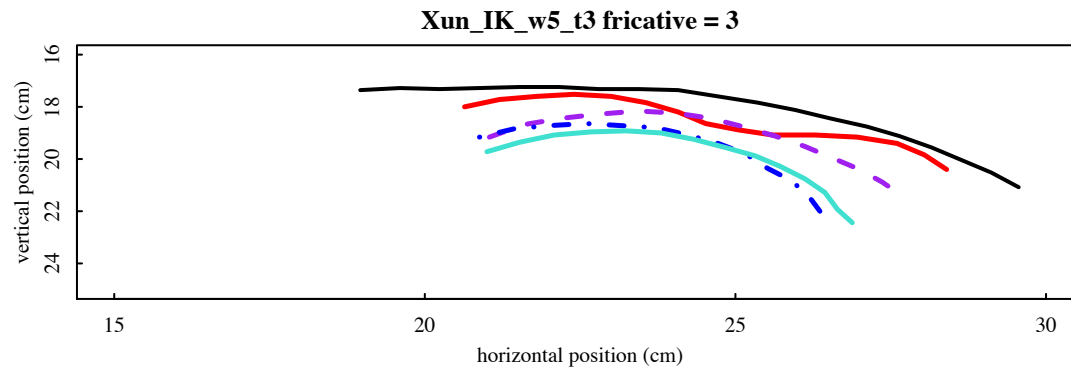


Figure 2. Speaker IK production of word initial [w] in the context of the frame sentence. One trace is for the frame 8.77ms before click release (red), and three traces in the fricative (trace 1, purple; trace 2, blue; trace 3, turquoise).

Although the data collection was designed to collect 36 tokens for each phone in each position (3 repetitions of the frame sentence in each take, 4 takes for each speaker, 3 speakers), the intensive nature of the articulatory data analysis in addition to difficulties with recording in the field resulted in less tokens for several phones. For duration, most phones resulted in full datasets. However, word initial /v/ had only 35 tokens, word medial /s/ and /h/ had 33 tokens, and word medial /h/ had 32 tokens. The exact number of tokens used in statistical analysis for articulatory measurements is shown in Table 7.

	Initial	/s/	/χ/	/h/	/v/	/w/	Medial	/s/	/χ/	/h/	/h/	/v/	/β/	/w/	/l/
# of Usable Tokens		36	35	35	35	35		33	34	26	15	36	36	36	36

Table 7. Actual number of usable tokens for articulatory measurements following data collection and analysis methods.

### Section 3.3 Acoustic Analysis

To measure duration, the auditory data were segmented into wav files, then imported into Praat (Boersma 2013) and the beginning and end of the frication noise were annotated in a text grid. The end of the following [a] vowel was also annotated for future research use. Figure 3 demonstrates a waveform, spectrogram, and corresponding annotated text grid for word initial [s] followed by an [a] vowel produced by Speaker DM.

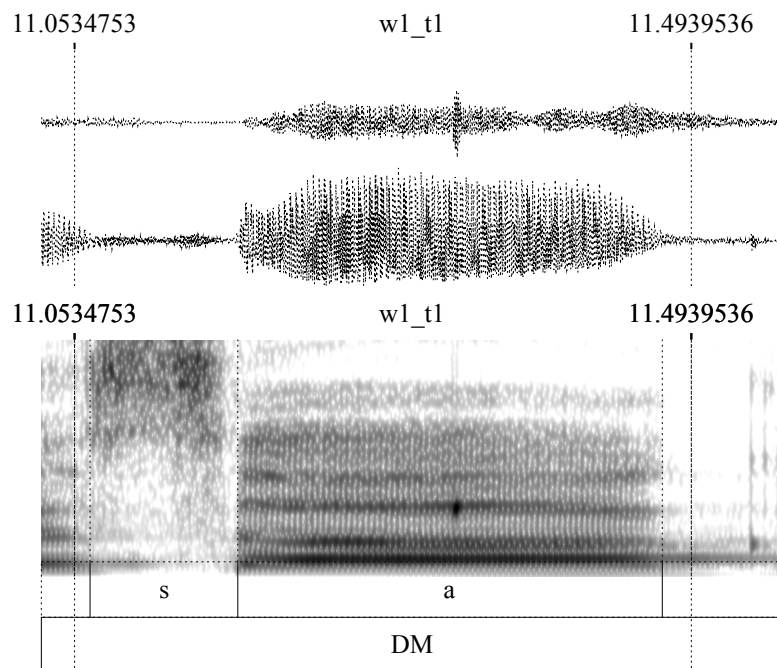


Figure 3. Spectrogram and corresponding annotated text grid for Speaker DM identifying the onset and end of frication noise for [s] in the auditory signal as well as the end of the following [a] vowel.

### Section 3.4 Articulatory Analysis

Constriction degree was measured as the smallest difference between the palate and tongue. An R script was written to identify the differences between all points on the palate trace to all points on the tongue trace. Identification of the constriction degree was then visually checked by the author for appropriateness of the measurement. The boxplots that show salient patterns or differences amongst speakers will be demonstrated in the sections below. The boxplots plot constriction degree against word and trace combined, so for [s], for example, the first box corresponds to the first trace in the word initial phoneme, and the last box corresponds to the last trace in the word medial phoneme. When viewing the boxplots, note that a smaller measurement illustrates a greater degree of constriction location as it indicates that the tongue peak is at the closest point to the palate.

Constriction location was measured as the highest point along the tongue trace. An R script identified the highest point, and the measurements were then checked by the author for appropriateness of the measurement. Similarly to the boxplots demonstrating constriction degree, the boxplots for constriction location plot constriction location against word and trace combined. The same comparisons have been made for constriction location as were made for constriction degree. Note that the measurements are relative to the palate. All of the palates were shifted to start at the same location, and the traces transformed to the appropriate place on the palates. We were unable to obtain stone palate casts for our speakers while we were in Namibia, so at this time, the measurements are calculated to be relative to the location of the palate (ie, “5 mm forward from the end of the palate) rather than being calculated in absolute measurements to the actual size of the speaker’s palate from a stone palate cast.

### Section 3.5 Statistical Analysis

Analysis of variance (ANOVA) models were applied for duration measurements, as well as for constriction degree and constriction location measurements. For constriction degree and location, an ANOVA was applied for each trace number with consonant type as the factor. There are thirteen consonant types for the three measures, CL, CD, and duration: four word initial fricatives ([s], [ʃ], [v], and [χ]), one word initial approximant ([w]), six word medial fricatives ([s], [ʃ], [h], [β], [v] and [χ]), and two word medial approximants ([w] and [l]). There are three trace numbers: the first trace is the first frame in the production of the fricative, the second trace is the midpoint between the first and third traces, and the third trace is the last frame in the production of the fricative. Tukey post hoc tests were used to perform pairwise comparisons of word initial vs. word medial phones, subset by trace number for constriction degree and location. For the three measures,  $df = 12$ . An alpha value of  $p < .05$  is used in this study.

### Section 4. Expected Results

For the farthest forward fricatives /β/ and /v/, like Shadle et al. (2008), I expected to find tongue shape reflecting the surrounding vowel contexts. However, as Shadle et al. saw variation where the tongue took the shape of either an [i] like or [u] like vowel, depending on speaker, I expected variation in tongue shape (constriction degree and location) across speakers. Based on Al-Khairy (2005) and Jongman et al.'s (2000) report that voiced fricatives were shorter in duration than voiceless, I would expect [β] and [v] to be shorter than the voiceless fricatives in this study: [s], [χ], and [h].

/s/, as a sibilant, is usually the most resistant to co-articulation (Recasens & Espinosa (2009)), so I expected the least amount of variation in constriction degree and constriction location for this sound. In line with the results reported in Al-Khairy (2005), Abu-Al-Makarem (2005), and Jongman et al. (2000), /s/ in word initial position is expected to be longest in duration followed by /s/ in word medial position due to /s/ being both a sibilant and voiceless.

Based on the known variation in Khoekhoe between [x] and [χ] and the results of /x/'s approximant-like variation in Navajo (Iskarous et al (2012)), I would consider there to be a possibility of discovering approximant-like variation in the production of /χ/. [χ] is expected to be shorter in duration than [s], with word initial [χ] being longer than word medial [χ].

I am not currently aware of any study that looks at articulatory gestures in glottal fricatives, so I could only hypothesize here about potential results for these phonemes. Based on the transcriptions in the database, I expected to find both a voiced and voiceless glottal fricative. I would like to note that there was some doubt about this expectation in my mind because /h/ was transcribed as occurring only in word medial position, so I was uncertain as to whether this was actually a phoneme or just a fluke in transcription. Also, in line with the consistent pattern across fricatives in Shadle et al.'s (2008) study, if the same patterns are found for fricatives in Mangetti Dune !Xung, I would expect to find more advanced tongue root for the voiced glottal fricative, /fi/, than for /h/, and I hypothesize that the voiced variant would have a greater constriction degree than the voiceless variant.

## **Section 5. Results**

### **Section 5.1 Duration**

It was expected that, as word initial position is thought to be a stronger position, the fricatives and approximants in that position would have longer duration than the fricatives and approximants in word medial position. However, this was not always the case. The scope of this study was not wide enough to include normalized duration data (ie, duration of the fricative divided by the duration of the word), so it is possible that this additional adjustment would provide different results. Overall, word initial [s], [h], [v] and [w] followed expectations - word initial duration was longer than word medial duration. Also as expected, word initial [s] had the longest mean duration out of all the sounds considered. A significant difference was found for both [v] and [h], comparing the phones for word initial versus word medial positions.

Word position comparison data for [β], [h], and [l] are not available as these sounds do not occur in word initial position in the currently documented words of Mangetti Dune !Xung. However, it is worth noting that voiced sounds were expected to be shorter than voiceless, and [β] was the shortest of all the sounds in the study.

Unexpectedly, [χ] in word initial position was 8.35 ms shorter than [χ] in word medial position. This difference is not significant. It should be noted that [χαχα], ‘old man,’ is the only word in this dataset where the same fricative is found within the same word. It is possible that this durational difference is due to a property of the word, as if in the case that the emphasis is on the second syllable of the word. It may also be the case that, underlyingly, the second syllable [χα] is, in some way, considered its own prosodic word.

Duration means and standard deviations are reported in Table 8 and are also presented in a bar graph for quick comparison in Figure 4.

<b>Fricatives</b>	<b>Word Initial</b>	<b>Word Medial</b>
[v]	84.65 ms (10.42)	64.12 ms (12.84)
[β]		59.22 ms (10.65)
[s]	105.50 ms (12.17)	96.97 ms (13.51)
[ʃ]	81.81 ms (16.63)	63.13 ms (21.40)
[h]		75.62 ms (21.03)
[χ]	89.36 ms (10.42)	97.71 ms (17.33)
<b>Approximants</b>		
[w]	85.12 ms (23.99)	74.94 ms (20.16)
[l]		76.77 ms (12.9)

Table 8. Fricative and approximant duration means. Standard deviation in parentheses following the mean. Empty cells demonstrate the lack of these sounds in Mangetti Dune !Xung in these word positions.

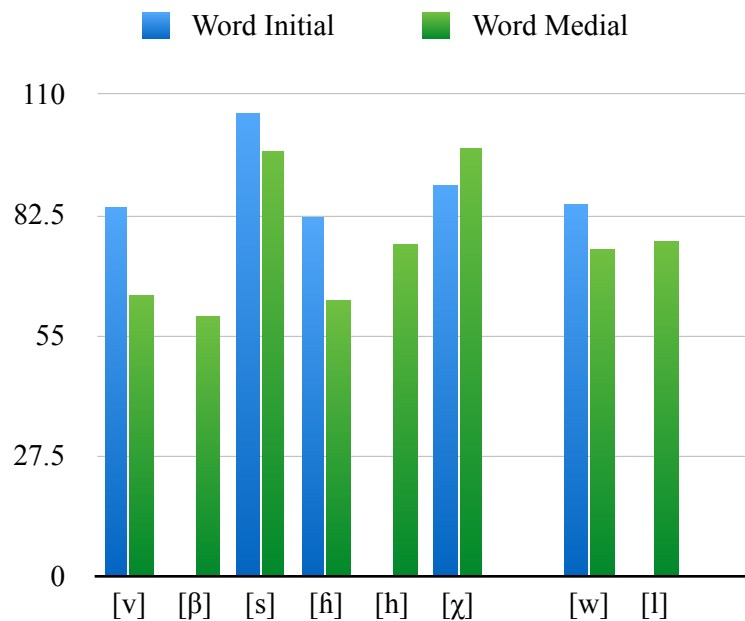


Figure 4. Bar chart of fricative and approximant duration means presented in Table 7. Presented visually for easy comparison.

## Section 5.2 Constriction Degree

An ANOVA for each trace was run with constriction degree as the result, and the word type as the factor, averaged across speakers. The ANOVA for each trace was significant ( $p < .0001$ ). The results for a Tukey posthoc test are provided in Table 9 below.

CD	s_med	h_med	h_med	x_med	v_med	β_med	w_med	l_med
s_init	NS	—	—	—	—	—	—	—
h_init	—	NS	NS	—	—	—	—	—
h_med	—	—	Trace 1	—	—	—	—	—
x_init	—	—	—	NS	—	—	—	—
v_init	—	—	—	—	NS	NS	—	—
w_init	—	—	—	—	—	—	All traces	Trace 2

Table 9. Pairwise comparisons for consonant types for the model constriction location by consonant type. Cells for traces where a comparison was significant are filled in with corresponding trace number. NS = not significant, — = a comparison was not necessary.

### Section 5.2.1 [s]

Figure 5 presents boxplots comparing [s] in word initial position, by speaker to [s] in word medial position, by speaker. All speakers demonstrate a smaller constriction degree for [s] in word initial position than for [s] in word medial position; however, the difference between word initial and word medial position is not significant for any trace. Note the variation amongst speakers: the difference in constriction degree between word positions is larger for speaker JF than for speaker DM. Speaker IK's results were similar to Speaker DM. No speaker demonstrates a pronounced difference between the first trace of [s] in word medial position (preceded by [a]) to the first trace of [s] in word initial position (preceded by [e] in frame sentence), suggesting that [s] was resistant to coarticulation with the [a] vowel (Recasens & Espinosa 2009).

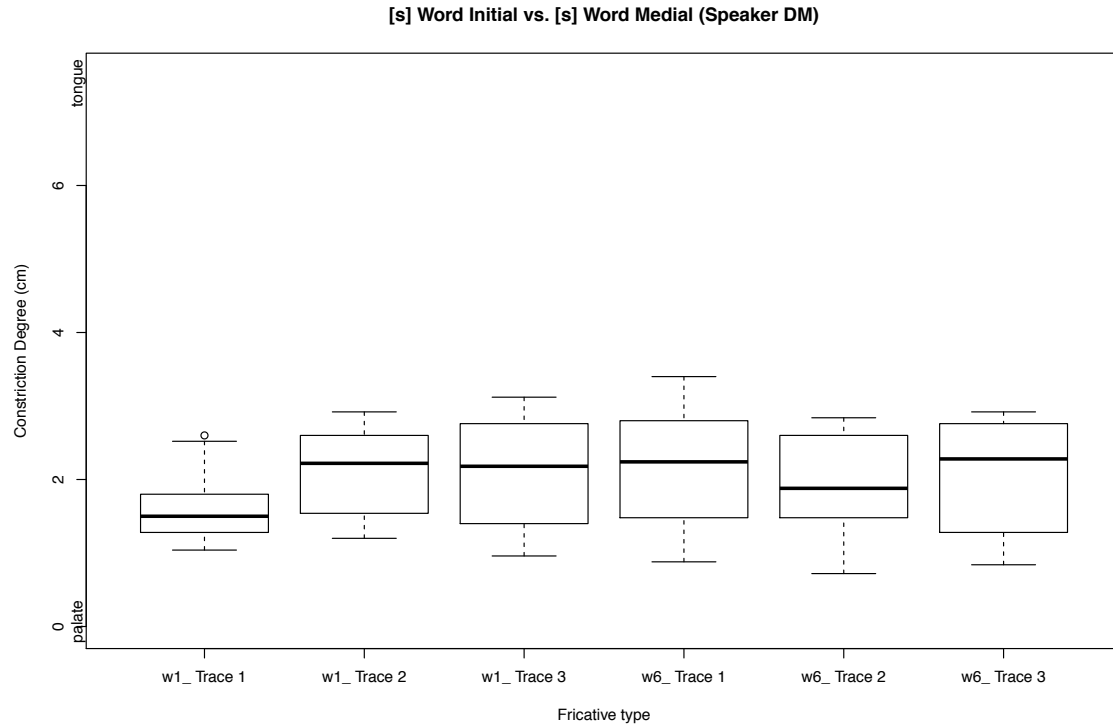
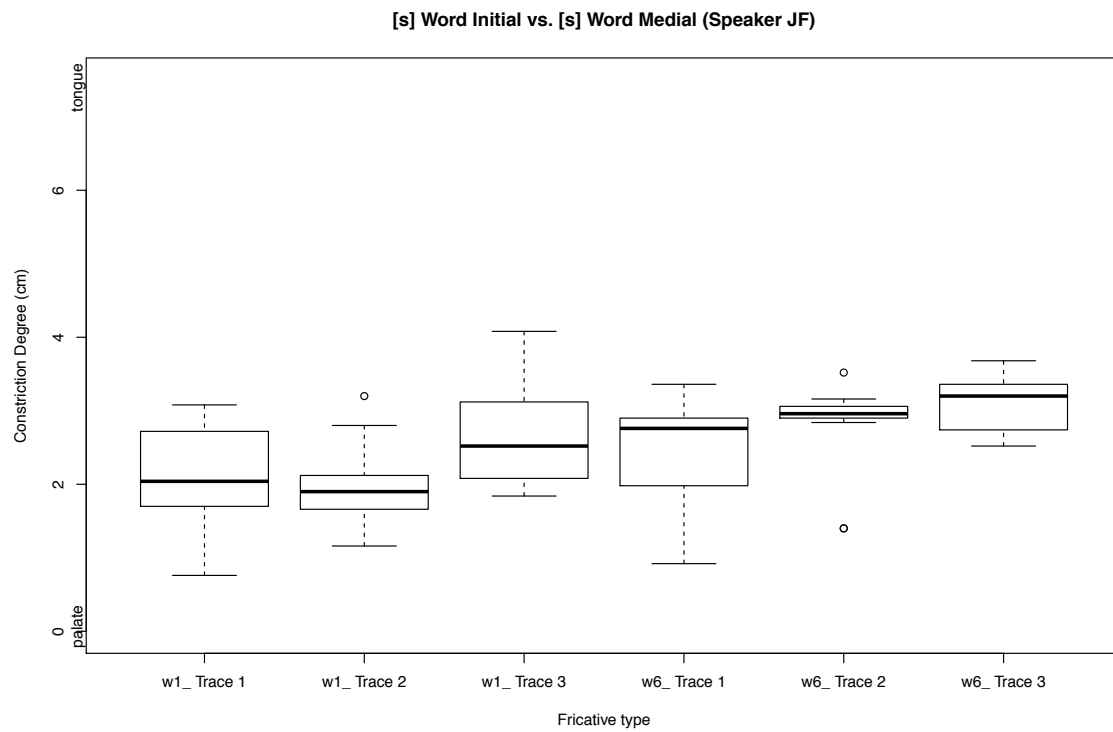
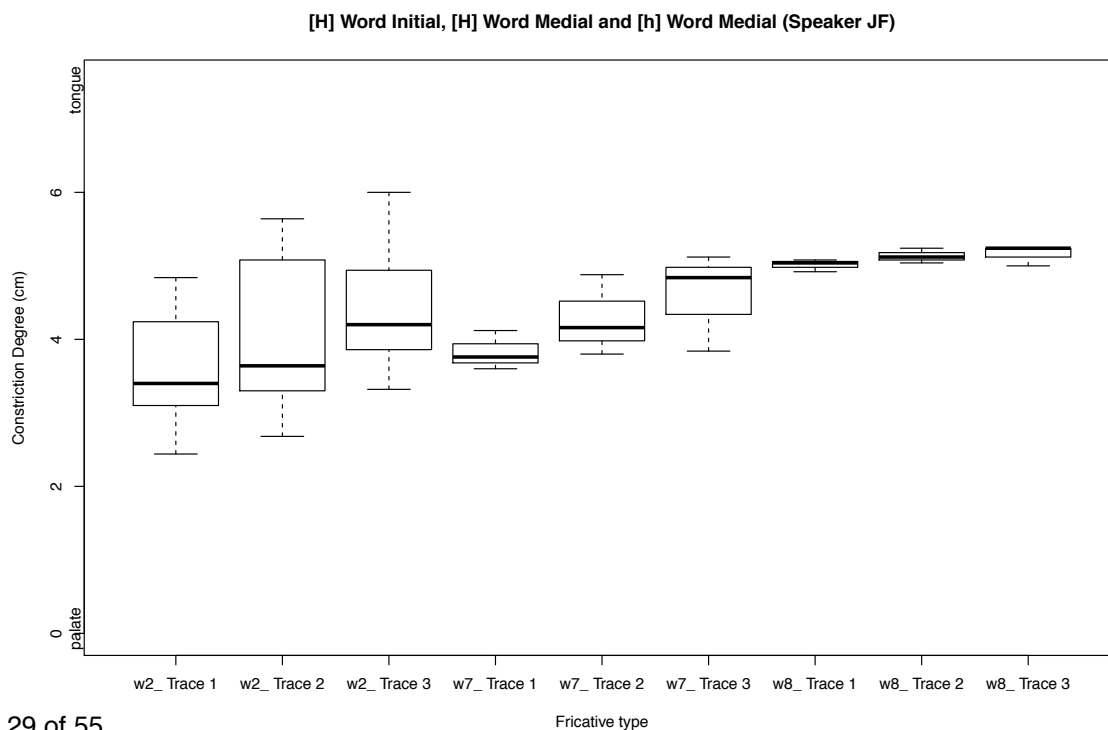


Figure 5. Constriction Degree (CD) for Speakers JF and DM productions of [s] in word initial (w1) and word medial (w6) positions separated by trace.

### Section 5.2.2 [ɸ] and [h]

Figure 6 presents boxplots for Speakers JF and DM comparing constriction degree for [ɸ] in initial and medial position as well as [h] in medial position. [h] is included here because it does not have corresponding word initial data. There is a general pattern across words and speakers for the first trace to demonstrate the greatest constriction degree, the second trace to have a slightly lesser constriction degree than the first trace, and the third trace, having the least constriction degree, to be essentially in position to begin the following low, back vowel, [ɑ]. The only exception to this pattern is with speaker DM for the word medial [h].

Speaker JF shows a greater constriction degree for word initial [ɸ] than for word medial [ɸ] or [h], although the effect is more pronounced for [h] than [ɸ], and the difference between word medial [h] and word medial [ɸ] is significant ( $p < .05$ ). Speakers IK and DM demonstrated a greater constriction degree for word medial [ɸ] than word initial [ɸ], which is the opposite effect to what was expected.



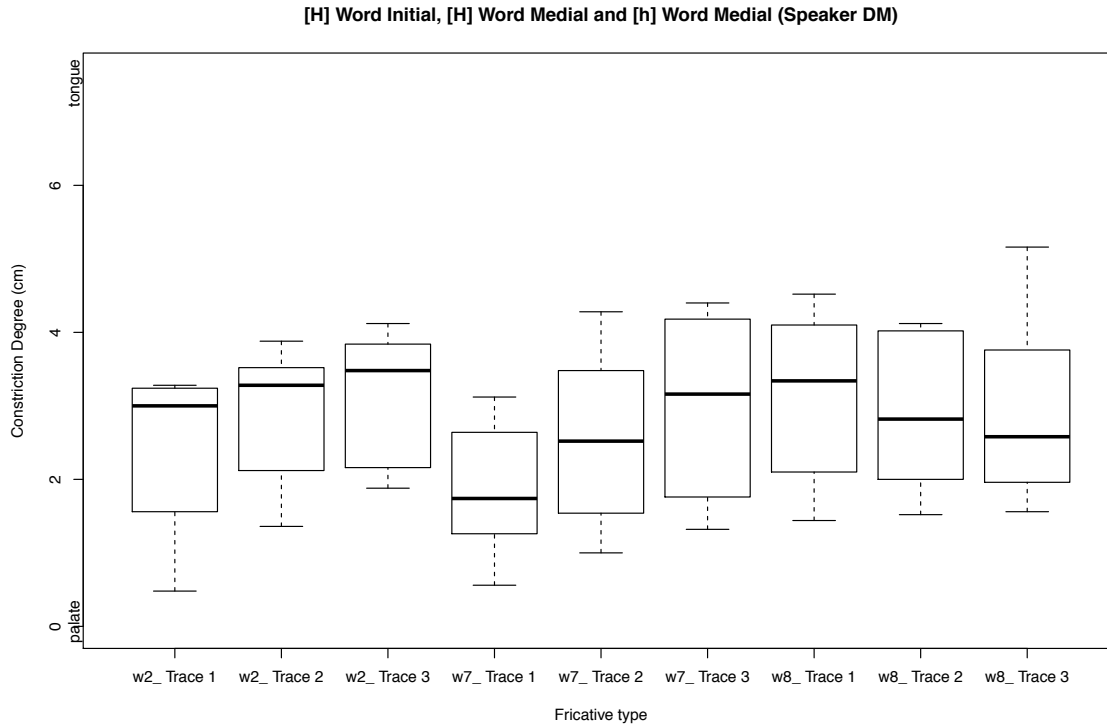


Figure 6. Constriction Degree (CD) for Speakers JF and DM's productions of [h] in word initial (w2) and word medial (w7) positions, and [h] in word medial (w8) position separated by trace.

### Section 5.2.3 [χ]

Figure 7 contains boxplots for [χ] in word initial position versus word medial position, by speaker. [χ] is unique in this study in that the word initial and word medial phonemes are both taken from the same word, [χαχα], 'old man.' Note the pattern in Speaker JF's productions of word medial [χ] - the constriction degree increases at the second trace, perhaps demonstrating the steady state of the fricative, with the first and third traces demonstrating a transition period between the surrounding [α] vowels. This pattern is most salient for speaker JF, although it is slight for all speakers. This pattern is not found for the word initial [χ], perhaps because it is transitioning from the high, front vowel [e] in the word [ke] in the frame sentence. It is possible, however, to see that the third trace is similar for the [χ] in both word positions. It is also notable

that the constriction degree for [χ] is comparable to the constriction degree for [s]; the difference in constriction degree between [χ] and [s] was not significant.

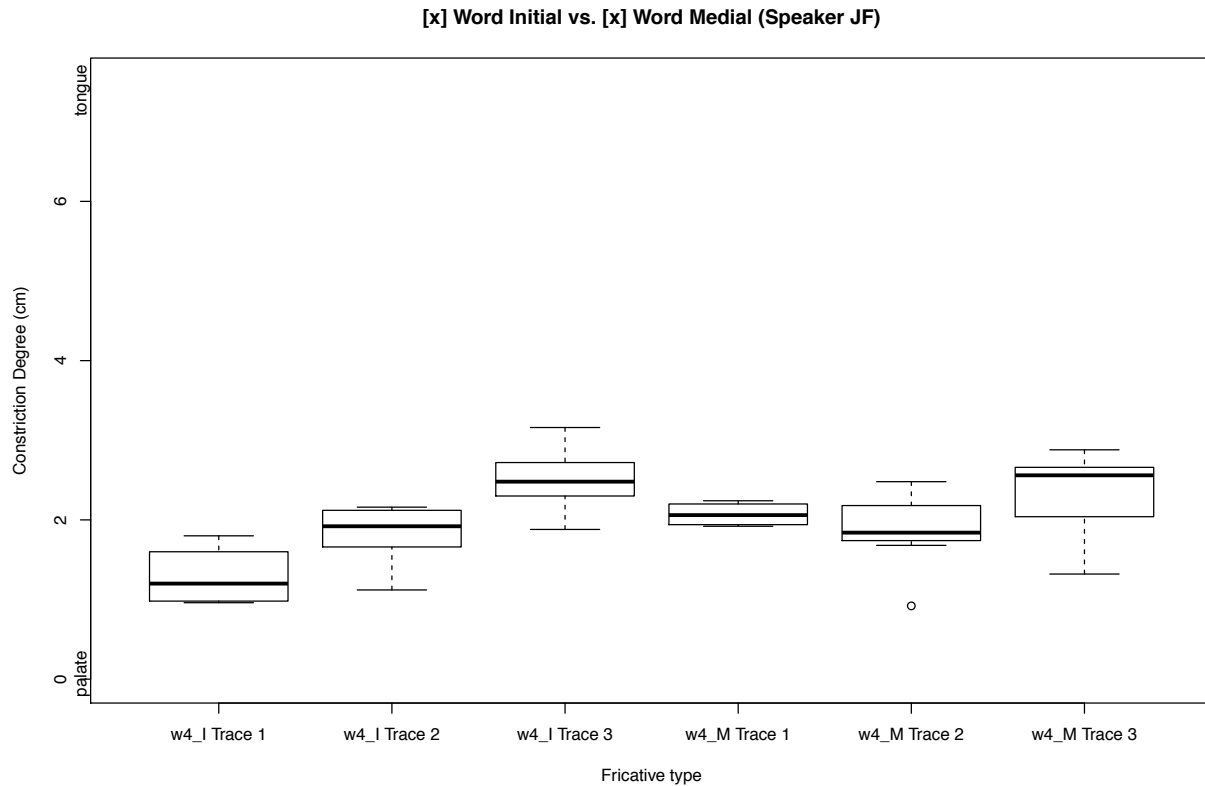


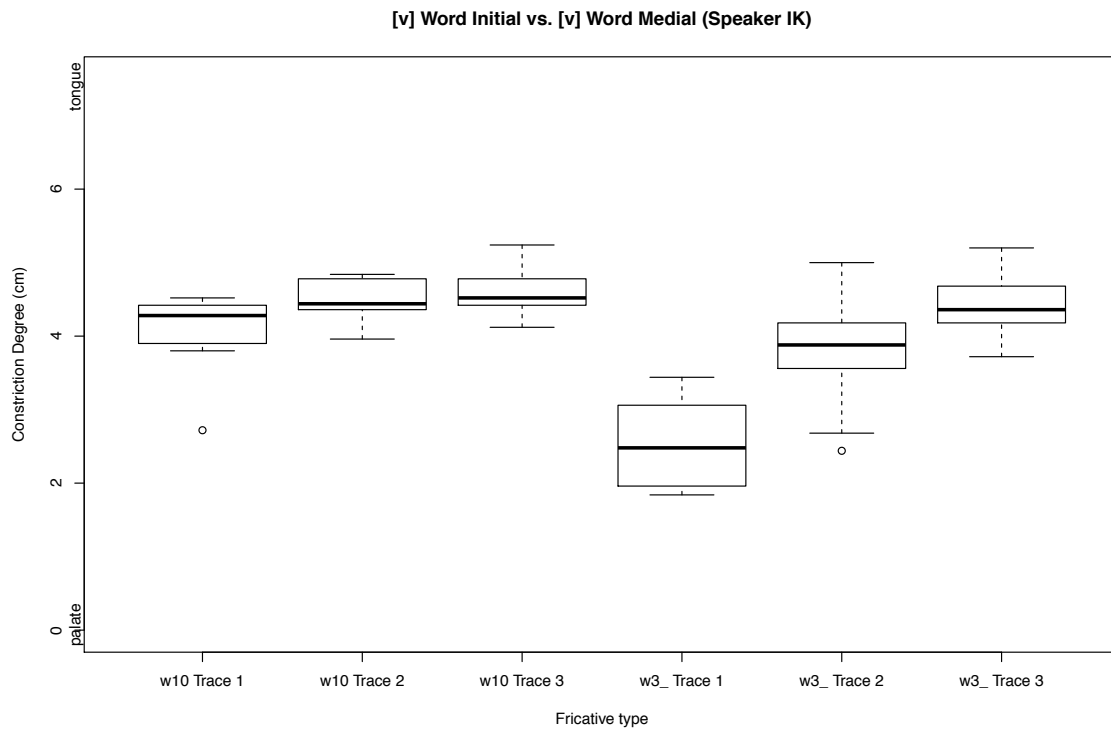
Figure 7. Constriction Degree (CD) for Speaker JF's productions of [χ] in word initial (w4\_I) and word medial (w4\_M) positions, separated by trace.

#### Section 5.2.4 [v]

Figure 8 contains boxplots for [v] in word initial and word medial positions, for speakers IK and DM. In these boxplots, the word medial [v] is plotted in the first half of the boxplot, and the word initial [v] is in the second half of the plot. The pattern for [v] is reminiscent of the pattern for [ɦ] and [h], although the constriction degree is less for [v] than for [ɦ] or [h]. The first trace demonstrates the greatest constriction degree, and the second and third traces lessen the constriction degree, most likely in preparation for the following low, back vowel, [ɑ]. Again

similarly to [ʃ] and [h], the only exception to this pattern is for speaker DM's word medial production of [v] which shows very little variation at all. Speaker IK demonstrates a larger amount of variability in the first trace of her production of [v], but she follows the general pattern.

Speakers JF and IK demonstrated a lesser constriction degree for word medial [v] than for word initial [v], but the difference was slight and not significant. Speaker DM has a slightly greater constriction degree for word medial [v] than for word initial [v], which is the opposite of what was expected.



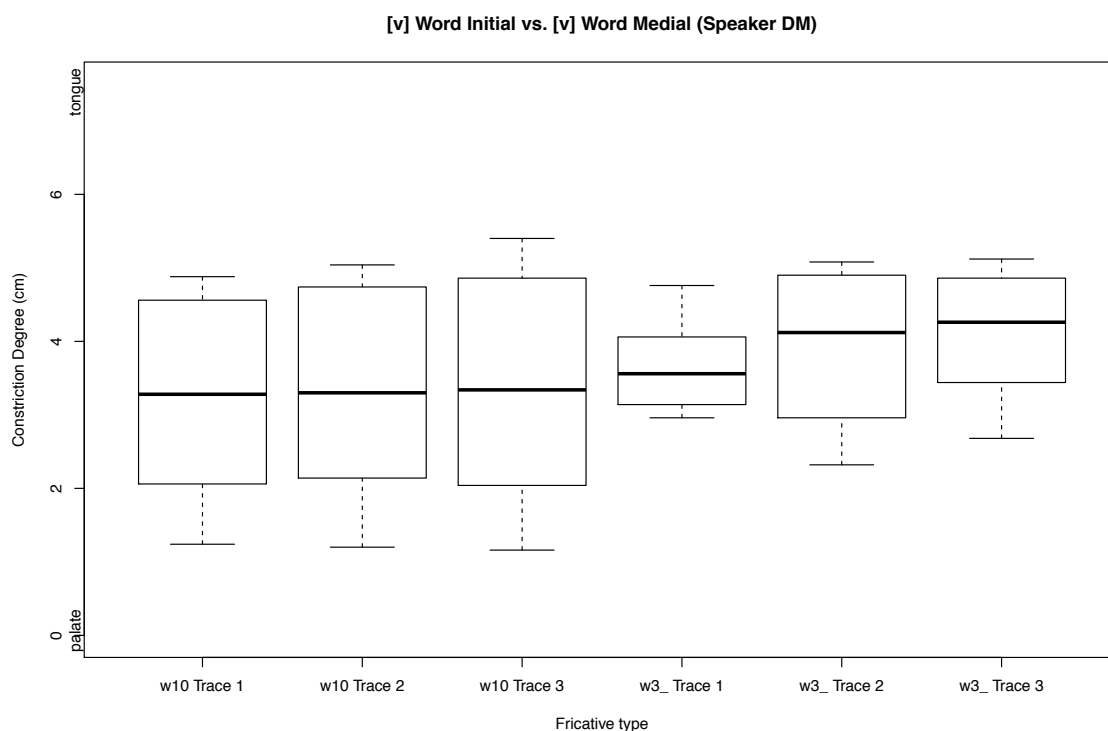


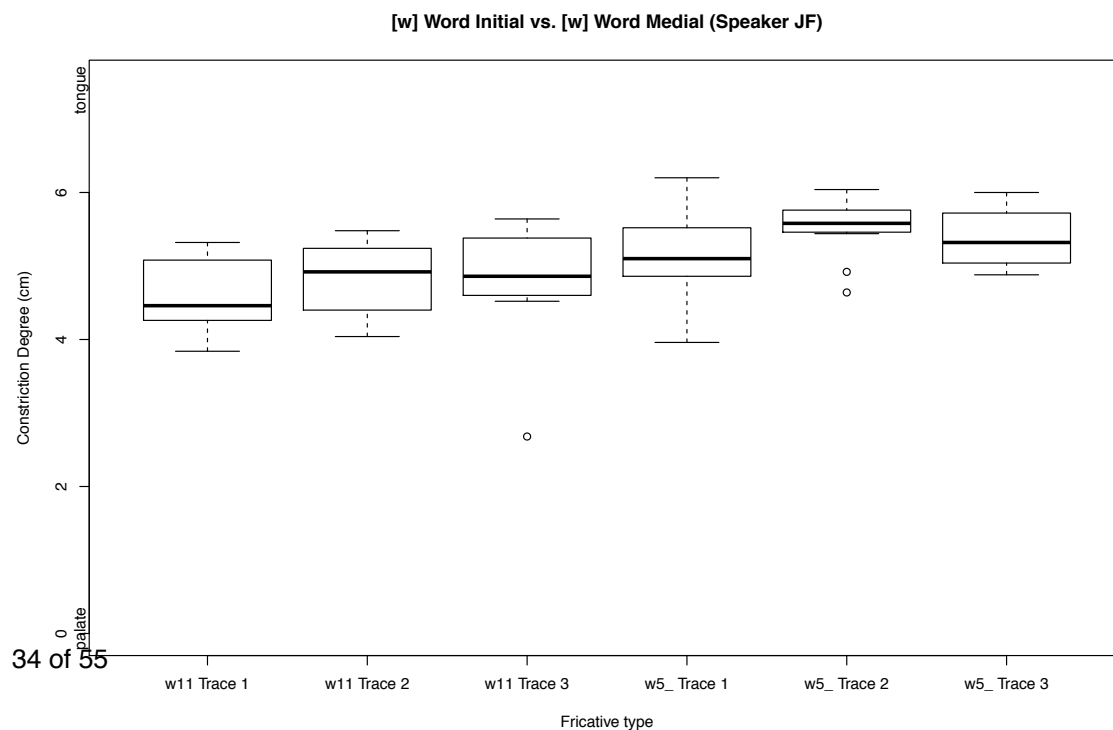
Figure 8. Constriction Degree (CD) for Speakers IK and DM productions of [v] in word initial (w3) and word medial (w10) positions, separated by trace.

### Section 5.2.5 [w]

Figure 9 presents boxplots for [w] in word initial and word medial positions, by speaker. As in the boxplots for [v], word medial [w] is displayed in the first half of the boxplot, and word initial [w] is in the second half. Two speakers, IK and DM, follow a similar pattern to that found in [h/ħ] and [v] (the constriction degree decreases from the first trace to the third trace), although the overall constriction degree is greatest for [h/ħ] and least for [w]. The pattern is also more pronounced for [h/ħ] and [v] than for [w]. Speaker DM shows only very little variation in the three traces for either word initial or word medial [w] but does show a considerable difference between overall constriction degree in word initial vs. word medial productions of [w]. This may be due to coarticulation with the previous vowel in the word glaowa. This is the only word in the

dataset that has a high, back vowel rather than a low, back vowel in the context surrounding the target sound. This exception was made due to an inability to find a word medial example of [w] with [ɑ] on both sides in the currently documented words of Mangetti Dune !Xung. Speaker JF has a different pattern from the other two speakers, however, this pattern is demonstrated for both the word initial and word medial productions of [w]. Speaker JF's pattern is similar to the pattern found in [χ], although in the opposite direction. Rather than increasing the constriction degree in the “steady state,” as in [χ], Speaker JF's [w] decreases the constriction degree during the second trace. Note that no matter which pattern the speaker uses, [w], as an approximant, demonstrates the least amount of constriction degree of any of the phonemes discussed.

All of the speakers demonstrate a greater constriction degree for word medial [w] compared to word initial [w], and the difference between the word positions is significant for each trace ( $p < .05$ ). Although the difference is significant, to the author, the sound tokens still resemble a [w] sound, rather than another sound. Note that this difference is in the opposite direction to what was expected.



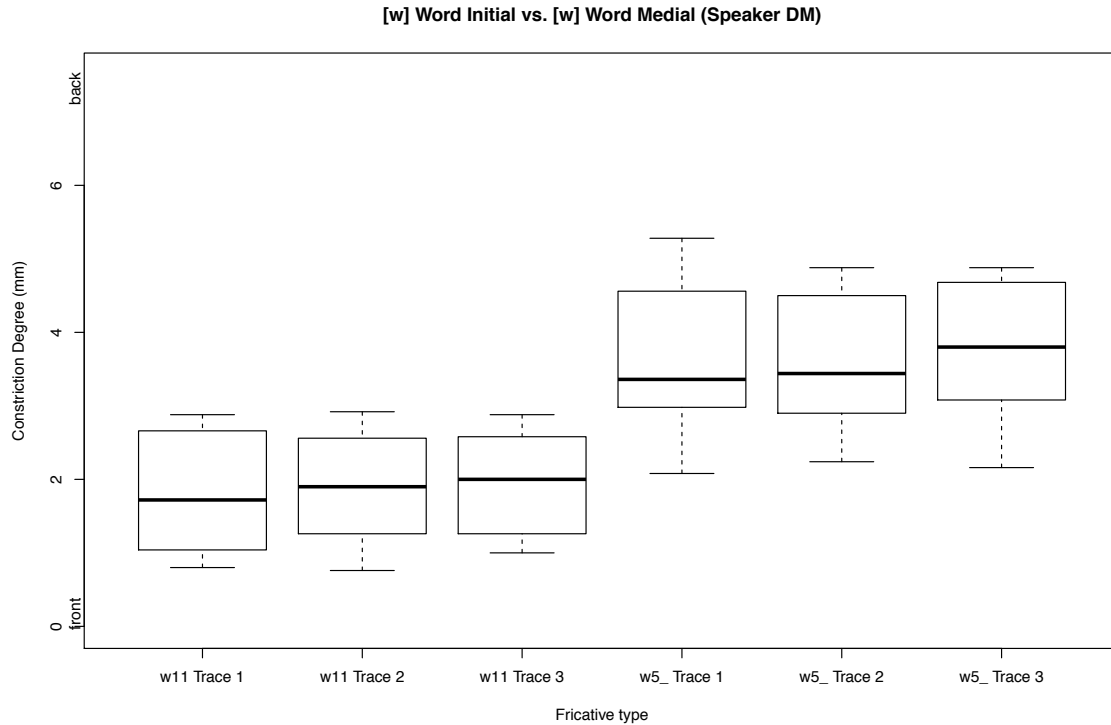
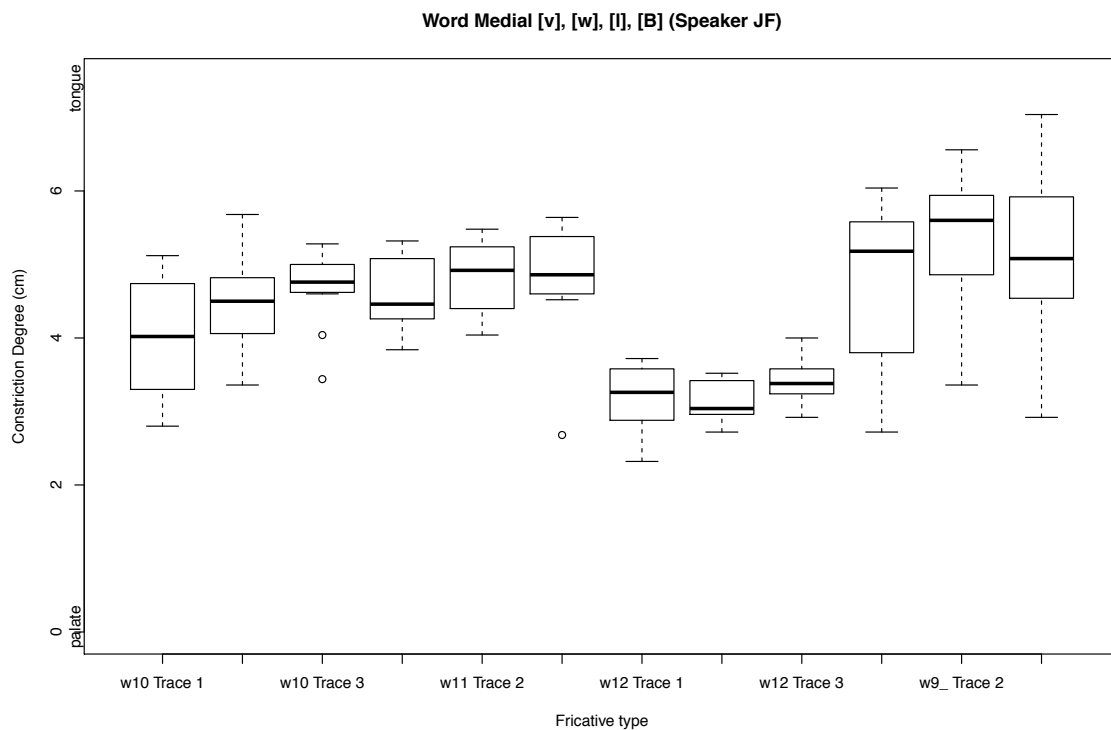


Figure 9. Constriction Degree (CD) for Speakers JF and DM productions of [w] in word initial (w5) and word medial (w11) positions, separated by trace.

#### Section 5.2.6 [β] and [l]

Figure 10 presents boxplots for [v, w, l, β] in word medial position, by speaker. Both [l] and [β] do not occur in word initial position in the currently documented words of Mangetti Dune !Xung, so these sounds are compared here to the word medial sounds, [v, w]. [v] was chosen as a comparison to [β] because [v] is closest in place of articulation and allows for similar freedom for tongue variation, and [w] was chosen as a comparison to [l] because [w, l, and j] are the only documented approximants in Mangetti Dune !Xung, and as [j] is a glide, it was determined that [w] would be a more appropriate comparison because the overall goal is to compare fricatives to approximants.

Of the two fricatives, [v and β], [v] demonstrates a greater constriction degree through all of the traces. [w] has a much greater constriction degree than [l] through all three traces for Speaker DM, but Speakers JF and IK show a larger constriction degree for [l] than for [w]. This is may be due to the variability allowed by [w] using the lips as the primary articulators compared to [l] using the tongue tip as the primary articulator. Only for the second trace is the difference between [l] and [w] significantly different.



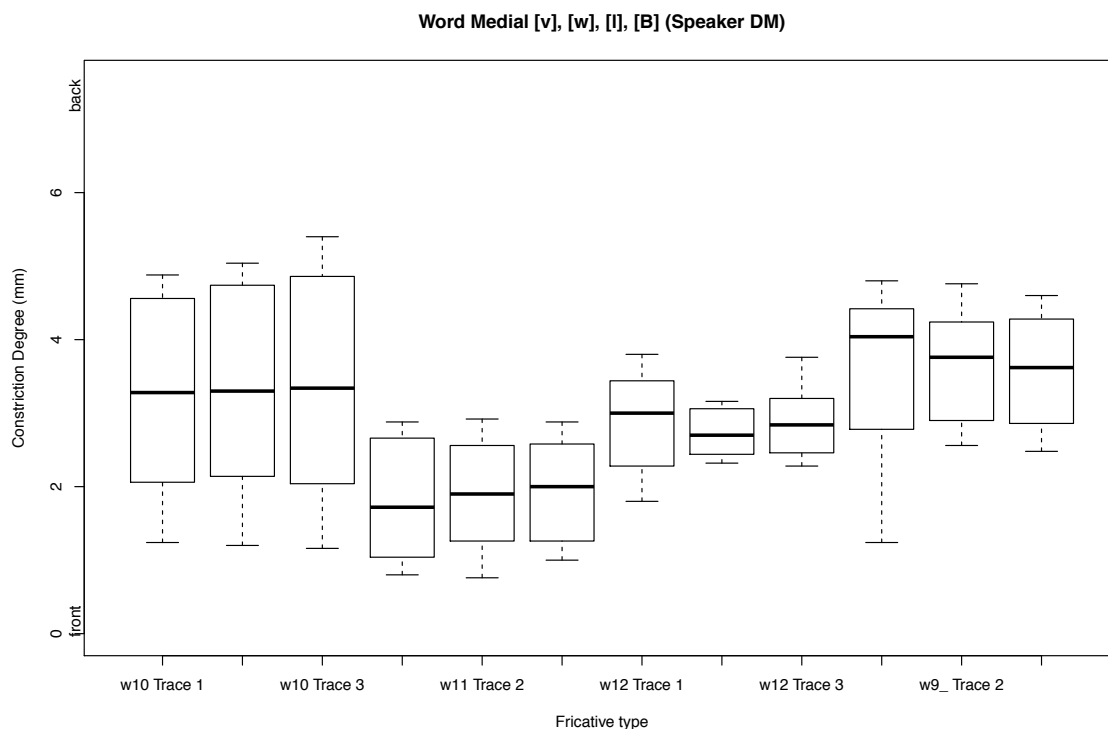


Figure 10. Constriction Degree (CD) for Speakers JF and DM's productions of [v, w, l, β] in word medial position (w10, w11, w12, w9, respectively), separated by trace.

### Section 5.3 Constriction Location

An ANOVA for each trace was run with constriction location as the result, and the word type as the factor, merged across speakers. The ANOVA for each trace was significant ( $p < .0001$ ).

The results for a Tukey posthoc test are provided in Table 10 below.

CL	s_med	h_med	h_med	x_med	v_med	$\beta$ _med	w_med	l_med
s_init	NS	—	—	—	—	—	—	—
h_init	—	NS	NS	—	—	—	—	—
h_med	—	—	NS	—	—	—	—	—
x_init	—	—	—	NS	—	—	—	—
v_init	—	—	—	—	Trace 1	NS	—	—
w_init	—	—	—	—	—	—	Trace 1	Trace 2

Table 10. Pairwise comparisons for consonant types for the model constriction location by consonant type. Cells for traces where a comparison was significant are filled in with corresponding trace number. NS = not significant, — = a comparison was not considered appropriate.

### Section 5.3.1 [s]

Figure 11 presents boxplots for [s] in word initial and medial position, by speaker.

The first trace for Speaker JF's word initial and word medial [s] is more forward than the other two traces, although the difference is more pronounced for word medial [s] than for word initial [s]. Speakers IK and DM do not demonstrate much movement in constriction location through time. The differences between word initial and word medial [s] are not significant for any of the traces.

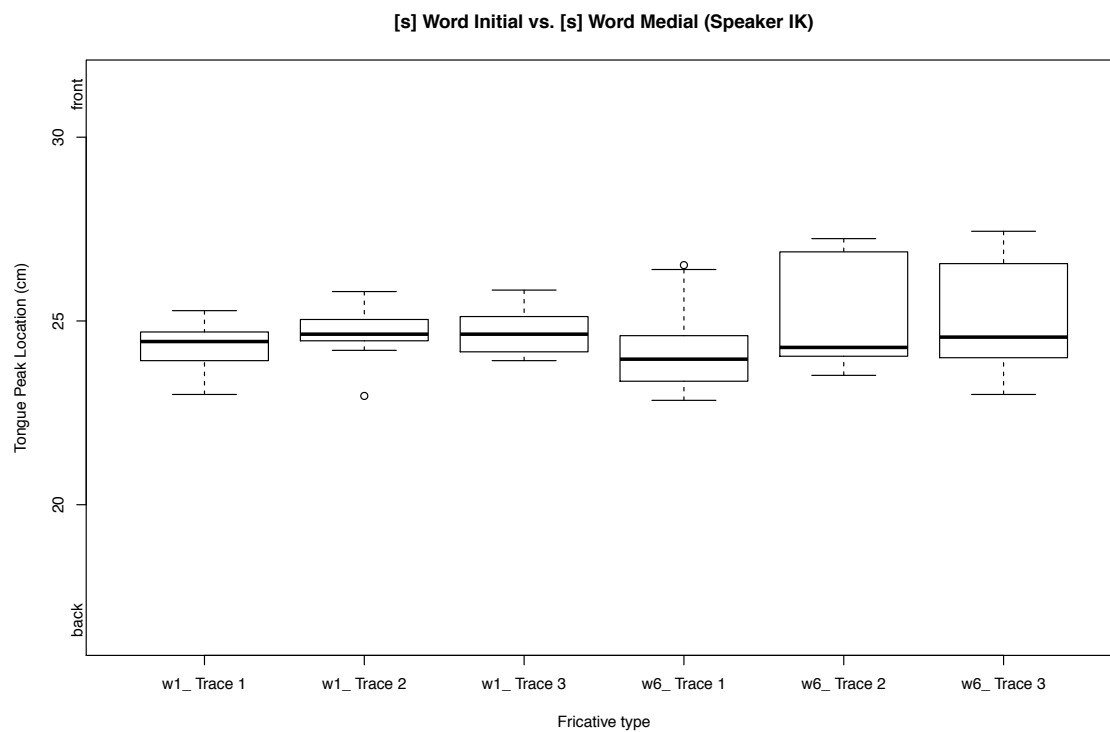
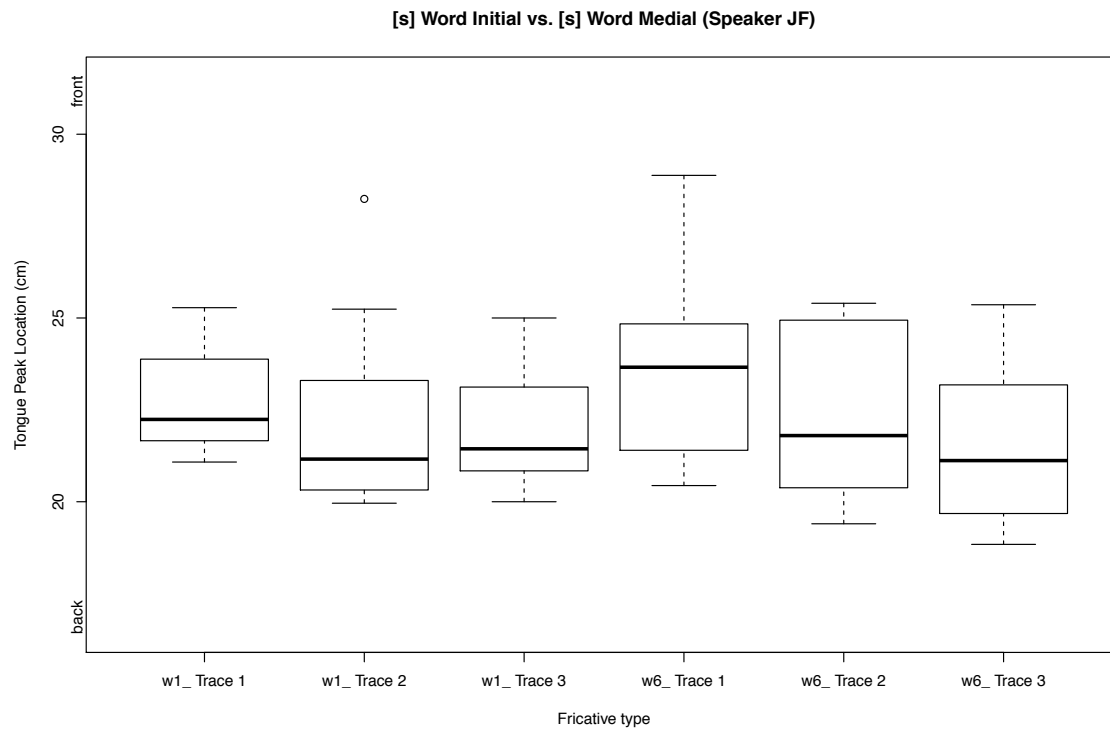
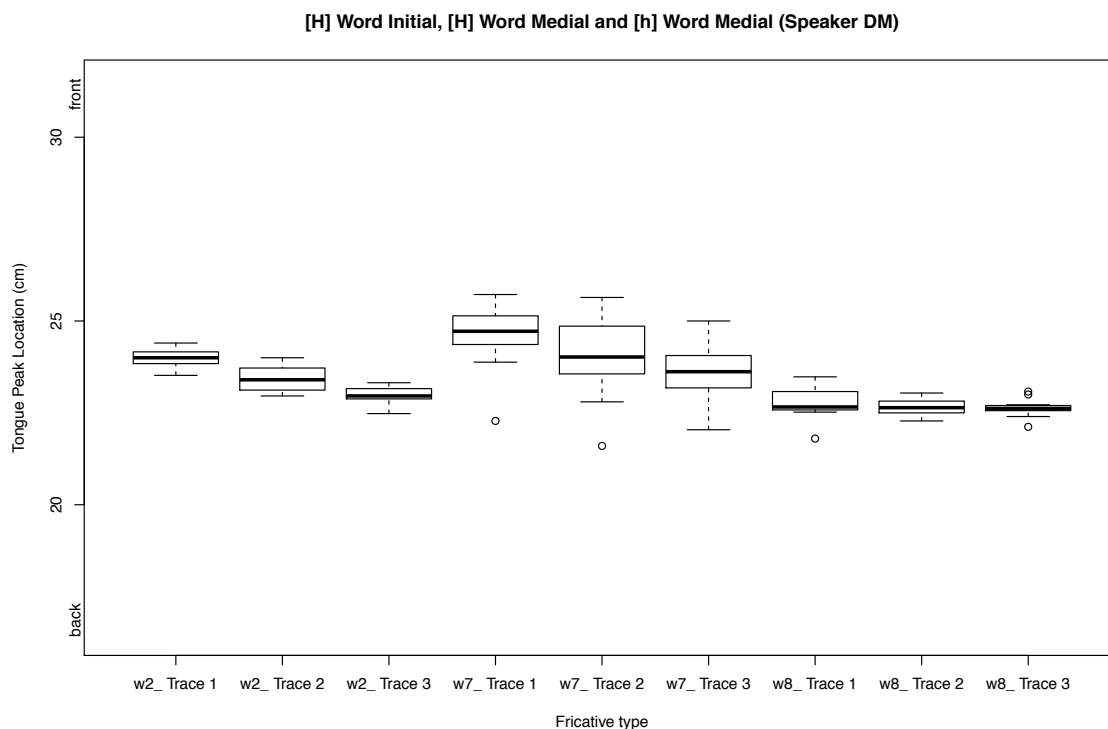


Figure 11. Constriction Location for Speakers JF and IK's productions of [s] in word initial (w1) versus medial position (w6), separated by trace.

### Section 5.3.2 [ɸ] and [h]

The box plots in Figure 12 demonstrate [ɸ] in word initial and word medial positions as well as [h] in word medial position. Speaker IK did not have any data for word medial [h] at the end of the data analysis, so only data from Speakers JF and DM were included in the final analysis.

Word initial and word medial [ɸ] follow a similar pattern: the first trace is the most forward, and the third trace is the farthest back. Word medial [h] for Speaker DM follows this same pattern, but for Speaker JF, the second trace is further forward than the first or third traces. Also, Speakers DM and JF demonstrate a more forward tongue posture during the first trace of word medial [ɸ] than word initial [ɸ]. Speaker IK does not demonstrate a difference between word positions.



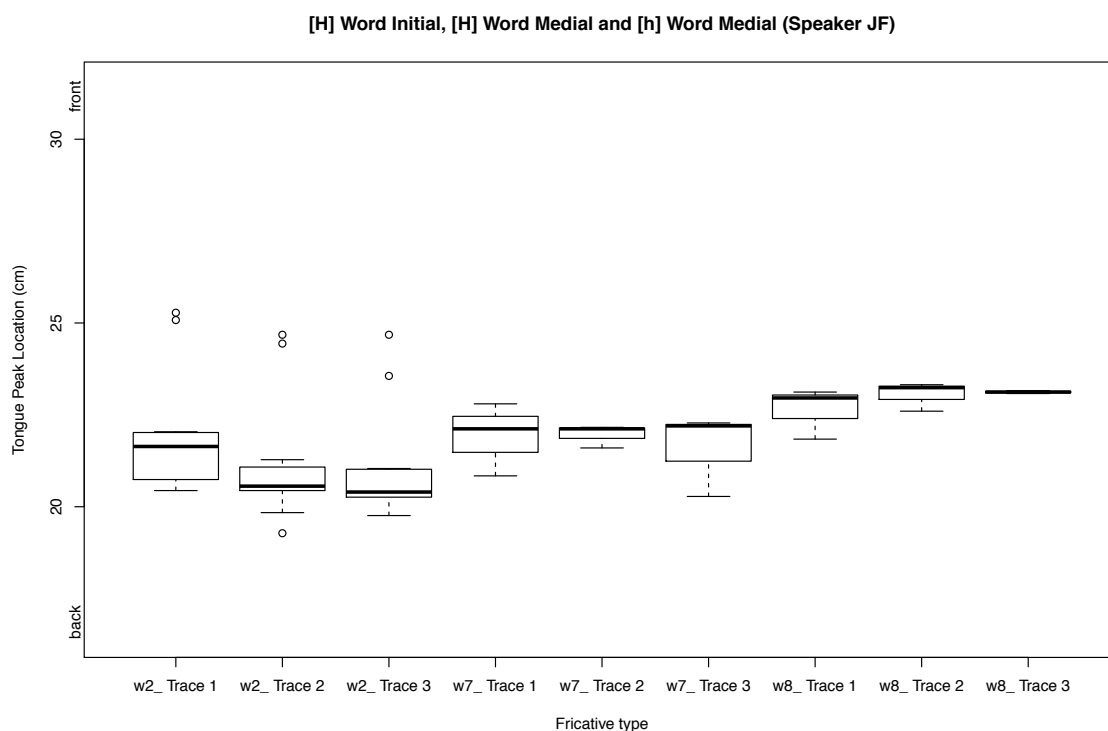


Figure 12. Constriction Location for Speakers JF and DM’s productions of [h] in word initial (w2) versus word medial position (w7), and word medial [h] (w8), separated by trace.

### Section 5.3.3 [χ]

Figure 13 presents boxplots for Speakers IK and DM for [χ] in word initial versus word medial positions, separated by trace. The general pattern found across traces, word positions, and speakers is this: the first trace is the most forward, the second trace is the farthest back, and the third trace is at a similar position to the second trace or is slightly farther forward than the second trace. Speakers IK and JF demonstrate farther forward word initial than word medial traces, for all three traces, which is likely due to coarticulation with the surrounding low, back [ɑ] vowel, but the difference is not significant. The first trace for speaker DM is farther forward in word medial than in word initial, and the second and third traces follow the same pattern as IK and JF.

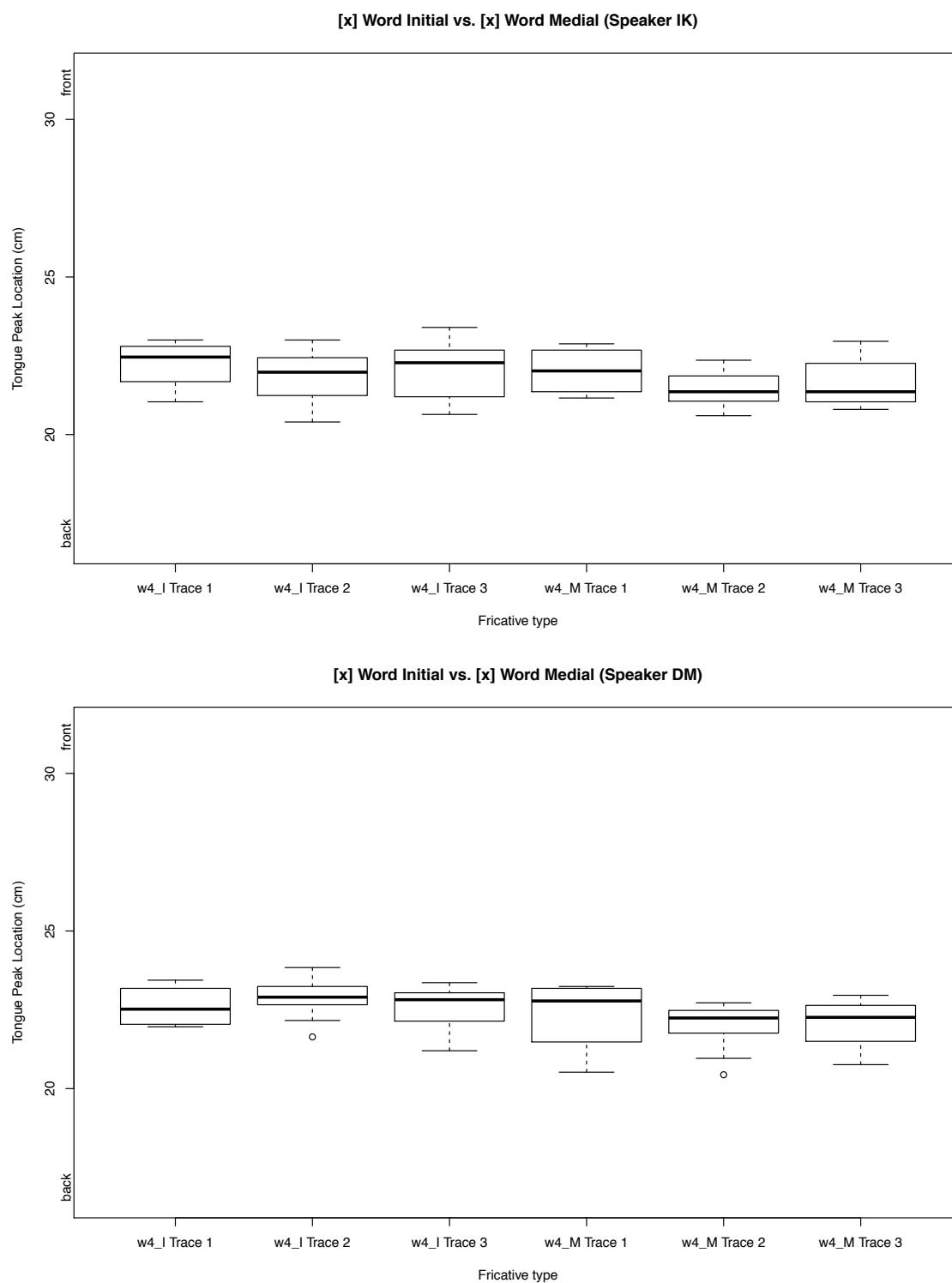
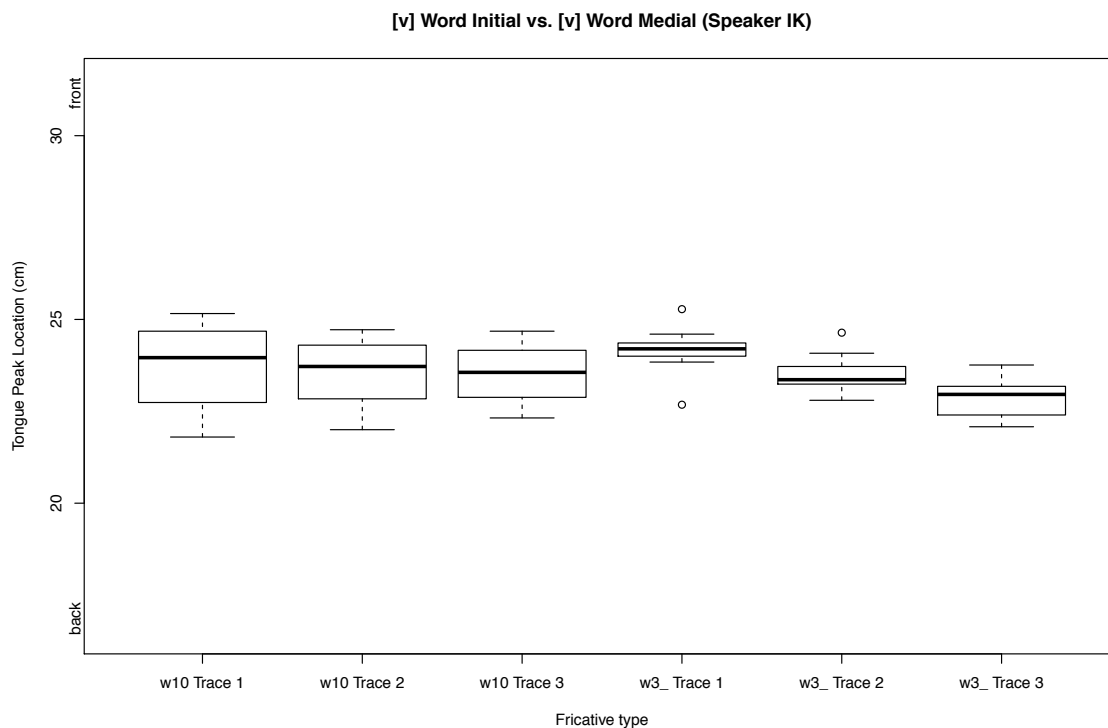


Figure 13. Constriction Location for Speakers IK and DM productions of [χ] in word initial (w4\_I) versus word medial position (w4\_M), separated by trace.

### Section 5.3.4 [v]

Figure 14 presents boxplots for Speakers IK and DM of [v] in word initial versus word medial positions, separated by trace. The first half of the boxplot represents [v] in word medial position, and the second half is [v] in word initial position. The first trace for all speakers in word initial position is farther forward than the first trace in word medial position, and the difference is significant ( $p < .05$ ). Speaker IK then follows a pattern in both word positions where the tongue moves farther back in the mouth throughout the following traces. Speakers JF and DM follow that same pattern for word initial [v], but in word medial position, the third trace is the farthest forward of the three traces in that position. This, perhaps, is related to an emphatic return to the following [a] vowel.



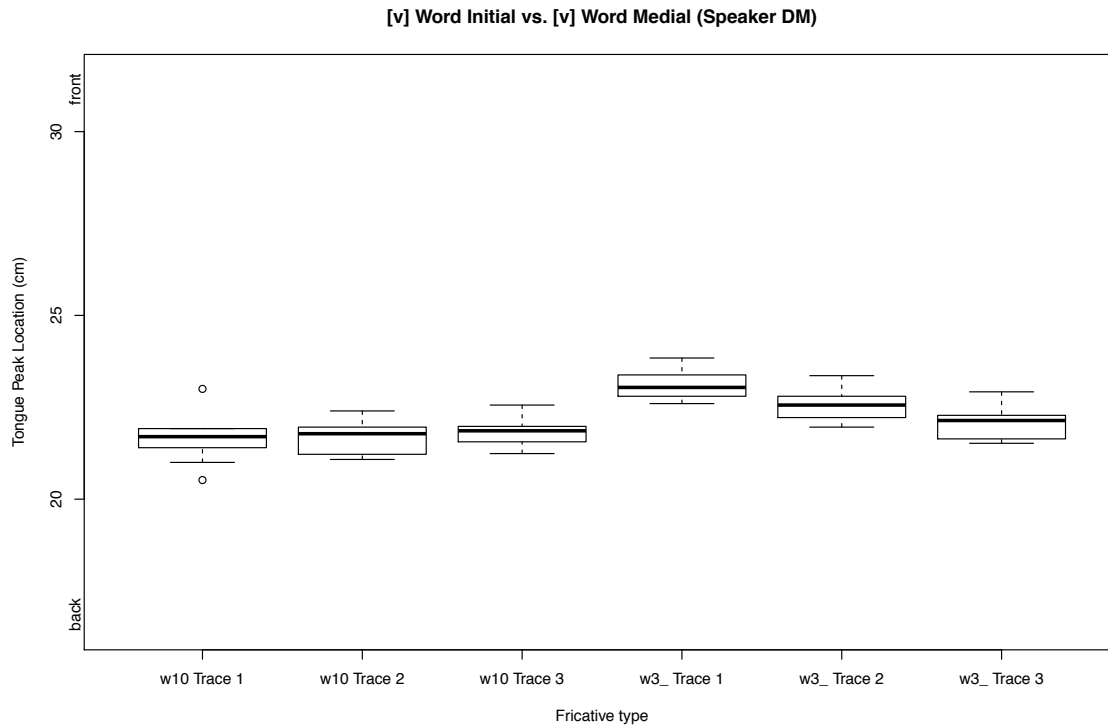


Figure 14. Constriction Location for Speakers IK and DM productions of [v] in word medial (w10) versus word initial position (w3), separated by trace.

### Section 5.3.5 [w]

Figure 15 contains boxplots for Speakers JF and DM's productions of word initial and word medial [w]. The first half of the boxplot is word medial position, and the second half is word initial position. The first trace in word initial [w] has a farther forward tongue peak location for all speakers than word medial [w], and the difference between the two positions for the first trace is significant ( $p < .05$ ). Tongue peak location for Speaker's IK and DM productions of [w] follow a similar pattern to one another. For word initial [w], the first trace is the farthest forward and each trace moves incrementally farther back afterward. Word medial [w] does not demonstrate much variety in tongue peak location for any of the traces. Speaker JF has different

patterns. The first trace in word initial [w] is the farthest forward, and the second trace is the farthest back. In word medial [w], the first trace is the farthest back and each trace moves incrementally farther forward.

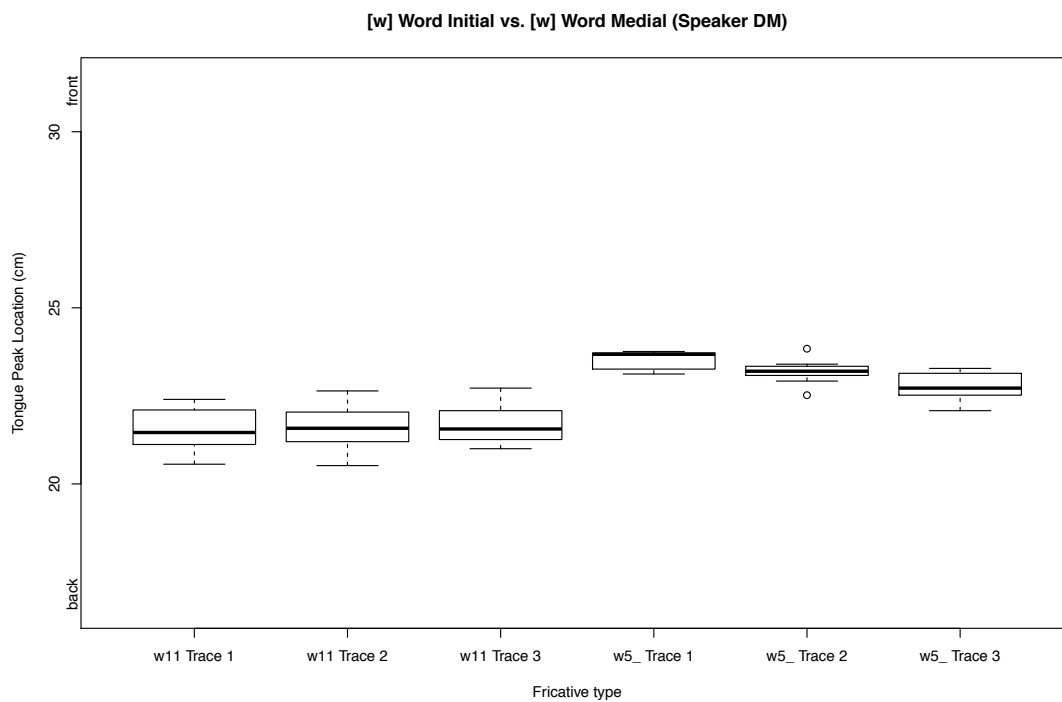
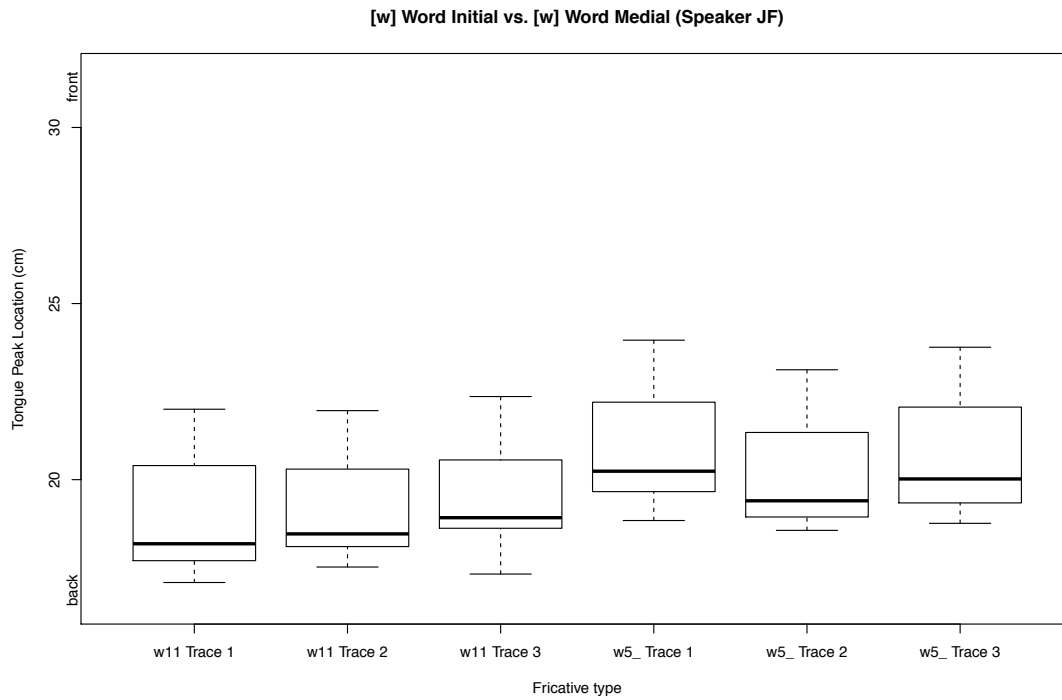
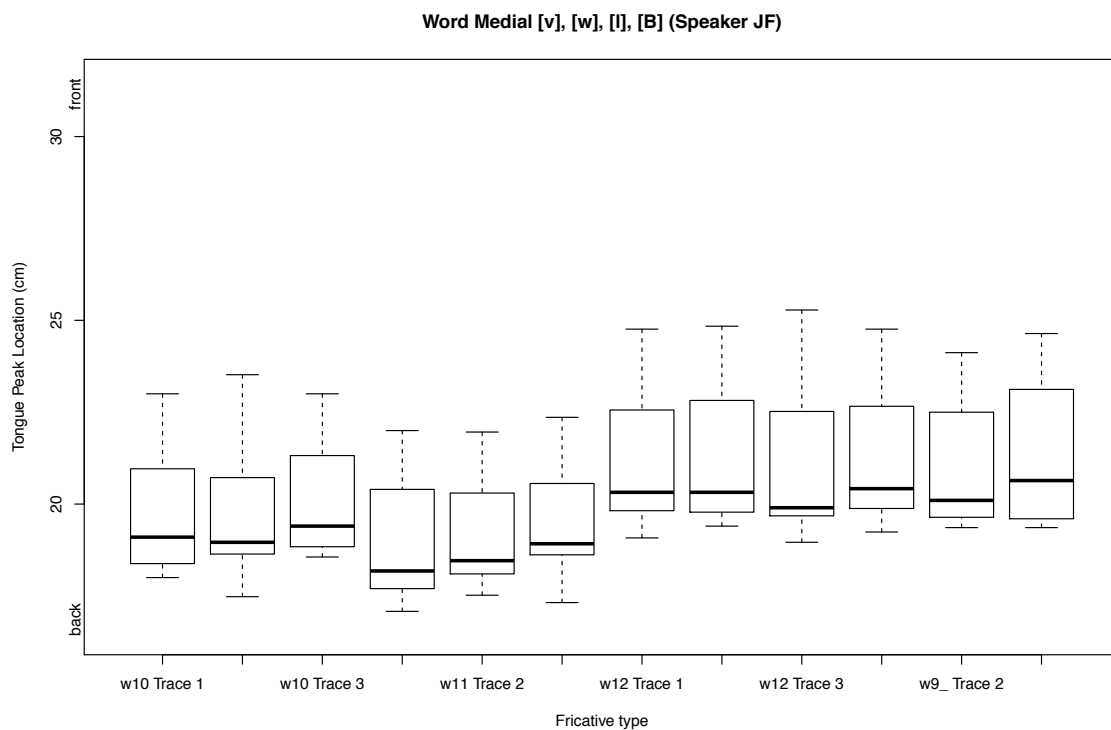


Figure 15. Constriction Location for Speakers JF and DM productions of [w] in word medial (w11) versus word initial position (w5), separated by trace.

### Section 5.3.6 [β] and [l]

Figure 16 presents boxplots for Speakers JF and DM for word medial [v, w, l and β], separated by trace. Speaker JF's production of [β] is most similar in movement through time (from the first trace to the third trace) to his production of [v], although [β] has a slightly farther forward tongue peak location. The production of [β] by Speakers IK and DM are most similar to [w], in that they did not demonstrate much variation throughout time.



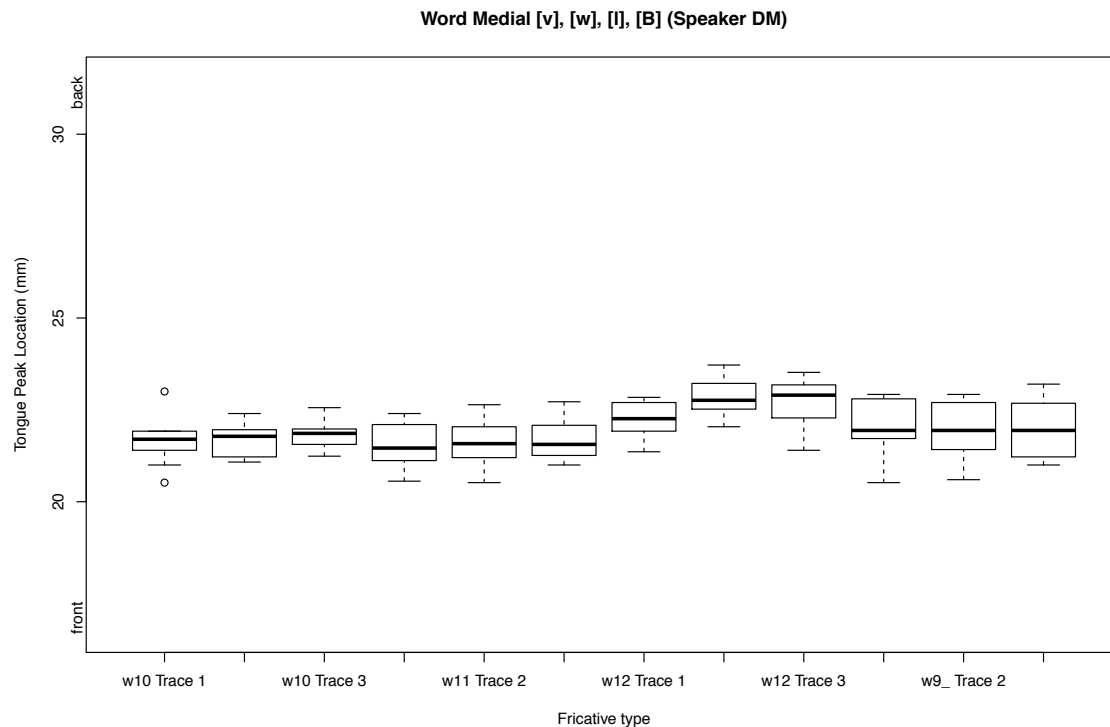


Figure 16. Constriction Location for Speakers JF and DM's productions of [v, w, l, β] in word medial position (w10, w11, w12, w9, respectively), separated by trace.

## **Section 6. Discussion**

### **Section 6.1 Summarizing [s]**

Similarly to results found by Jongman et al. (2000), Al-Khairi (2005), and Abu-Al-Makarem (2005), [s] in word initial position had the longest duration of all the fricatives and approximants. [s] in word medial position was not as long as [χ] in word medial position, but its difference from [s] in initial position was not significant, and thus supports the existing body of evidence that indicates that [s] is robust to co-articulatory effects, at least in the comparison of [s] in word initial position (preceded by [e] in the frame sentence) to [s] in word medial position (preceded by [a]). No results were significantly different for either constriction degree or

constriction location, similar to the articulatory resistance to coarticulation found by Shadle (2008), and the two female speakers did not demonstrate much variation in constriction location throughout the duration of the fricative. However, Speaker JF demonstrated a greater constriction degree throughout the entire fricative for word initial position compared to word medial position combined with a more forward constriction location in word initial first trace.

### Section 6.2 Summarizing [ɦ] and [h]

Word initial [ɦ] was found to be longer than word medial [h] which was then longer than word medial [ɦ]. This supports the previous evidence found in Jongman et al. (2000) for other fricatives that voiced fricatives are shorter in duration than their voiceless counterparts, although the difference was not found to be significant in a Tukey post hoc test. However, the difference between word initial [ɦ] and word medial [ɦ] was significant, thus providing support for Fougeron & Keating (1997) and Steriade's (1994) model of stronger consonants at domain boundaries.

Speaker JF had greater constriction degree for the word initial fricative than for either of the two word medial fricatives; however, Speakers DM and IK had greater constriction degree in the word medial fricatives, providing contradictory evidence for Fougeron & Keating (1997) and Steriade's (1994) models, or perhaps indicating that constriction degree is not a good indicator of the strength or weakness of a glottal fricative.

### Section 6.3 Summarizing [χ]

The duration results from [χ] provide some of the most surprising contradictory evidence (to Abu-Al-Makarem (2005)) in this study. Word medial [χ] had longer duration, not only of word initial [χ], but also of a voiceless sibilant, word medial [s]. A few possible explanations are

that the language considers this repetitive 2nd syllable to be underlyingly a different prosodic word, or that the word is a result of reduplication. It is also possible that acoustic strengthening was happening to increase the perceptual difference between the uvular fricative and the surrounding low, back vowels.

Iskarous et al. (2012) found fricative-approximant variation for [x] in word initial position, and those results were not replicated here for [χ]. Speakers IK and JF demonstrated a somewhat more forward constriction location and somewhat lesser constriction degree for word initial position than for word medial position, but neither measure was significantly different for these speakers, nor did they mimic the differences in constriction location and constriction degree demonstrated by other fricative-approximant pairs such as [v] and [w] or [ɦ] and [w].

#### Section 6.4 Summarizing [v]

The duration of the frication noise for word initial [v] was significantly longer than that of word medial [v], as was expected from the body of literature presented here and is more support for a stronger consonant at domain boundaries. Listening to the tokens obtained in the study revealed that word medial [v] can also sound like [w], so perhaps [w] is a word medial allophone of /v/ in Mangetti Dune !Xung. However, for now, it should be noted that this variability was entirely within the [a] context. It should also be noted that as significant results were only obtained for the voiced segments in this study ([ɦ], [v] and [w]), it is possible in Mangetti Dune !Xung, that voiced consonants participate in creating stronger consonants at domain boundaries but voiceless consonants do not.

The constriction location for the first trace was farther forward in initial position than in medial position for all speakers, but in all other parameters a large amount of inter speaker

variation was found in tongue position. Speaker JF had less constriction degree for word medial [v] than for word initial [v]. The constriction location of this speaker's production of [v] moved back progressively from the first trace to the third trace in word initial position, but in word medial position, the third trace was the most forward. Speaker DM had very little variation in constriction degree, but followed a similar pattern in constriction location as Speaker JF. Speaker IK followed Speaker JF's pattern for constriction degree, but was consistent across word positions in moving back in the mouth from the first trace to the third trace. This variability makes sense due to the large degree of tongue movement freedom in the production of a labiodental fricative.

#### Section 6.5 Summarizing [w]

Word initial [w] followed the expected pattern in duration: word initial [w] was longer than word medial [w], although the difference was not significant. Tongue movement throughout the three traces for constriction degree followed a similar pattern to that of [f] and [h], with less overall constriction degree. However, similarly to the unexpected results that word medial [f] had a greater constriction degree than word initial [f] for two speakers, [w] demonstrates a significantly greater constriction degree in word medial position than in word initial position. So, while [f], [h] and [w] follow similar patterns in constriction degree overall, they are perhaps distinguished primarily by the tongue dorsum being lower (having a lesser constriction degree) for [w] than for [f] or [h]. Also, the patterns for constriction location for [w] were similar to those of other consonants. In the first trace, word initial [w] was significantly farther forward than word medial [w], but in the second and third traces, there is a lot of inter speaker variability in tongue movement.

### Section 6.6 Summarizing [β] and [l]

[l] demonstrated the longest duration of all the word medial phones. It should be noted that it is possible that the saliency of [l] due to its length contributes to its high token frequency in the database. [β] demonstrated the shortest duration of all the phones in this study. Although [β] follows similar patterns to [v] and [w] articulatorily, it is significantly different in duration from both word initial and word medial productions of both of these other phonemes.

### Section 6.7 Summarizing Overall Contributions

I believe that this study has contributed to our understanding of phonological representation by increasing our knowledge of the differing ways that different speakers are using articulatory parameters to maintain contrast in their productions of different fricatives and approximants. At the end of this experiment, I expected to be able to report on individual speaker variability and different articulatory strategies used in production of different fricatives regarding tongue shape, constriction degree and location, and the acoustic durational cues described here, and this has been accomplished.

When completed, I expected this experiment to not only document more on Mangetti Dune !Xung, but also to have determined what specifically, if any, articulatory or acoustic parameters were regularly contributing to a phonetic basis for positional constraints in Mangetti Dune !Xung. Unfortunately, I cannot say that this is the case due to the high level of inter-speaker variation across both articulatory measurements. It seems prudent to acquire more data from more speakers to assess truly salient patterns before any firm claims are made. I also expected to be able to contribute information regarding our understanding of the acoustic and articulatory parameters of fricatives.

## **Section 7. Conclusion**

This paper describes what is already known about Mangetti Dune !Xung fricatives, approximants, vowels, and their word positions. I have shown that Mangetti Dune !Xung has been recorded as having 8 fricatives that occur variably in either word initial position, word medial position, or both positions, and that some fricatives, although occurring in both positions, occur more often in one position than the other. Despite being transcribed as having an 11 vowel inventory, I have described how three back vowels, [a], [o], and [u] tend to pattern more frequently with fricatives and in the language overall than front or central vowels, with the exception of [χ], which patterns with [ə] most frequently.

I have also surveyed the fricative inventories of three other languages similar to Mangetti Dune !Xung: Khoekhoe (Khe), N|uu (Tuu) and Ju|hoansi (Kx'a) in order to provide a basis for comparison of fricative inventories.

I have summarized the literature that I am currently aware of regarding acoustic and articulatory studies on fricatives that could inform my study. Iskarous et al (2012), Shadle et al. (2008), and Fougeron & Keating (1997)'s studies influenced my expected articulatory results, and Jongman et al. (2000), Abu-Al-Makarem (2005), and Al-Khairy (2005), influenced my expected acoustic results. My results have provided further support for the claims in those papers.

I also expected to be able to contribute information regarding our understanding of the acoustic and articulatory parameters of fricatives, and the results presented here demonstrated several interesting findings. The variability seen in /v/ suggests allophonic variation between [v] and [w] in word medial position, within an [a] context. Also, [w] was seen to have significant

differences between word medial and word initial position; however, that difference did not result in an easily perceptible difference, at least to the author. The results on /χ/ prompt further investigation - perhaps, overall, into gutturals in Mangetti Dune !Xung, and, specifically, into the word itself (reduplication, prosodic emphasis, etc.). The results for [s] provide further support for the claims made in the previous literature, and the results from [f] and [h] provide some support for the existence of both the voiced and voiceless phonemes in this language. These results have been presented here to the best of my ability.

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