Vowel quality and duration in Yukon Deg Xinag[*]

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1 Background

Deg Xinag is an Athabaskan language spoken in the western interior of Alaska. The Yukon dialect is the traditional language of the villages of Anvik, Shageluk and Holy Cross, although as of 2009 there are no longer any speakers living in Anvik and Holy Cross.[1] The language has also been known as Ingalik (e.g. Osgood 1940) and more recently as Deg Hit'an (Krauss 1974).[2]

1.1 Consonant inventory

The inventory of consonants found in Yukon Deg Xinag is given in (1)-(3) in both IPA (in //) and orthographic representations (in <>). (1) contains consonants which can occur in syllable-initial position.[3] The Deg Xinag inventory is 'large' from a cross-linguistic point of view (Maddieson 2005), even when two of the 44 consonants in (1) (/p p^h/, found only in loan words) are removed. Compared to other languages of the family, Deg Xinag also has 'a rather full Athapaskan consonant system' (Krauss 1962). The large number of places of articulation in the Yukon Deg Xinag consonant inventory is due to the fact that the Proto-Athabaskan **š*ʳ-series has not merged with any other sibilant series in Deg Xinag (Yukon dialect),[4] and the **k*ʸ-series has developed into both /k/ and /ʧ/ in an apparently unconditioned split.[5]

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[1]A very small amount of data from the Kuskokwim (K) dialect is cited in this paper. However, unless accompanied by '(K)', all data in this paper are from the Yukon dialect.

[2]"Deg Hit'an" rather than "Deg Xit'an" is a somewhat unfortunate spelling choice. *Xit'an* is the orthographic representation of /χət'an/ 'people of (area)', a nominalized verb form. There is no contrast between /χ/ and /h/ in the verb prefixes of Deg Xinag, and acoustic evidence indicates that the normative pronunciation in that context is [χ] rather than [h] (Wright et al. 2008).

[3]I use two transcription systems in this paper to make the information accessible to non-Athabaskanists (who would presumably prefer IPA) as well as Athabaskanists, who are used to viewing the syllable-initial voiceless unaspirated stops and affricates with "voiced" symbols. Throughout this paper IPA is given in [] or //; orthography is italicized or placed in <>. The Deg Xinag practical orthography was designed by Krauss 1962 and further modified by Kari 1974.

[4]The basic contrasts of the Proto-Athabaskan consonant and vowel inventories were worked out by Krauss 1964, but see Leer 2005 for the latest version of the Proto-Athabaskan segment inventories. This paper generally uses Leer's

(1) Yukon DX consonant inventory (syllable-initial position)

/p/ <b>	/t/ <d>	/tθ/ <ddh>	/ʦ/ <dz>	/tɬ/ <dl>	/ʈʂ/ <dr>	/ʧ/ <j>	/k/ <g>	/q/ <G>	
/p^{h}/ <p>	/t^{h}/ <t>	/tθ^{h}/ <tth>	/ʦ^{h}/ <ts>	/tɬ^{h}/ <tl>	/ʈʂ^{h}/ <tr>	/ʧ^{h}/ <ch>	/k^{h}/ <k>	/q^{h}/ <q>	
	/t'/ <t'>	/tθ'/ <tth'>	/ʦ'/ <ts'>	/tɬ'/ <tl'>	/ʈʂ'/ <tr'>	/ʧ'/ <ch'>	/k'/ <k'>	/q'/ <q'>	/ʔ/ < ' >
		/ð/ <dh>	/z/ <z>	/l/ <l>	/ʐ/ <zr>			/ʁ/ <gh>	
		/θ/ <th>	/s/ <s>	/ℜ/ <ɬ>	/ʂ/ <sr>	/ʃ/ <sh>		/χ/ <x>	/h/ <h>
/m/ <m>	/n/ <n>						/ŋ/ <ng>		
/v/ <v>						/j/ <y>			

In syllable-final position, the aspirated and ejective stops and affricates do not occur, as in most other Athabaskan languages. Instead there is a contrast between voiceless unaspirates and voiced stops and affricates, as is typical of Alaskan Athabaskan languages.

(2) Stop/affricate contrasts (syllable-final position)

	/d/ <d>	/dð/ <ddh>	/ʣ/ <dz>	/dl/ <dl>	/ɖʐ/ <dr>	/ʤ/ <j>	/g/ <g>	/ɢ/ <gg>	
/p/ <b>	/t/ <t>	/tθ/ <tth>	/ʦ/ <ts>	/tɬ/ <tl>	/ʈʂ/ <tr>	/ʧ/ <ch>	/k/ <k>	/q/ <q>	

The voiced stops and affricates are historically predictable from a following vowel (e.g. Proto-Athabaskan **-k^{y}ətɬ'e:* 'younger brother' (Leer 2006-2010: k^{y}/53)[6] > -/ʧ^{h}ədl/ *-chidl*).[7] However,

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transcription system for Proto-Athabaskan, where **d* = voiceless unaspirated alveolar stop, **t* = voiceless aspirated alveolar stop, **dž* = voiceless unaspirated palato-alveolar affricate, **dž̌* = voiceless unaspirated retroflex affricate (with sibilant release), **g^{y}* = voiceless unaspirated palatal stop, **ŋ^{y}* = palatal nasal, **G* = voiceless unaspirated uvular stop, **ẏ* = voiced uvular fricative, **x̣* = voiceless uvular fricative, **y* = palatal glide.

[5]Krauss 1962 notes that the Deg Xinag palato-alveolar affricates 'correspond with those in other languages which show front or unrounded vowels', whereas the velar stops correspond 'with forms in other languages which show back or rounded vowels or PA structurally labialized consonants in final position.' However, he also notes that 'more work will have to be done before the differentiation can be explained completely…'

[6]Most reconstructions cited in this paper are taken from the *Comparative Athabaskan Lexicon* (Leer 2006-2010), although in place of Leer's 'O_N-' (indicating possessive prefix to noun required) I simply have a hyphen in front of reconstructed nouns, and in place of 'O_P-' to indicate object of postposition prefix required, I simply use 'P', as in Kari 1990. I retain Leer's 'O-' to represent a verbal object prefix (standard in Athabaskan linguistics), and his '=', representing a clitic (or disjunct verb prefix) boundary.

The *Comparative Athabaskan Lexicon* was compiled over a period of years, and in the first chapters completed, reconstructions are not flagged in the usual way, with 'PA *'. Instead, we find entries like *B P O-…=zə-*

synchronically /dl/ also occurs word-internally in the verb prefixes (< **hə-* + *s-* conjugation + *ɬə-* “classifier” Leer 2000) when a coronal stop or affricate follows (Hargus 2008).

Syllable-finally there are additional contrasts in glottalization and voicing among nasals and glides.

(3) Nasal and glide contrasts (syllable-final position)

[m] <m>	[n] <n>						[ŋ] <ng>		
[m’] <m’>	[n’] <n’>						[ŋ’] <ng’>		
[m̥] <mh>	[n̥] <nh>						[ŋ̊] <ngh>		
						[j] <y>			
						[j’] <y’>			
						[j̊] <yh>			

The glottalized sounds in (3) appear restricted to word-final position, where they may be analyzed as clusters (/m’/ etc.). The voiceless sonorants in (3) are mostly restricted to word-final position with the exception of [n̥], which is also synchronically attested word-internally.[8] Historically, glides and nasals were devoiced in word-final position unless a vowel followed (Krauss 1962, Leer 2008), the vowel preserving the original voicing of the sonorant. This is the same process that resulted in innovative voicing contrasts among stops and affricates in that position, as seen in (2).

1.2 Vowel inventory

Krauss 1962:25b noted that Deg Xinag has the set of vowel phonemes in (4), a ‘rather peculiar system of full vowels, characterized by a complete lack of close vowel phonemes’:

ɬ-a: ‘mistreat, abuse O’, where the ‘B P’ in front of the reconstructed form indicates that reflexes are attested in the B (= British Columbian) and P (Pacific Coast) subbranches of the family. I have nonetheless treated such forms in this paper as PA reconstructions, even when not explicitly labeled as such by Leer.

[7]When reflexes of PA words are given in this paper, the DX gloss of the lexical item is omitted if the PA word has not undergone any semantic change.

[8]Word-internal [n̥] *nh* occurs in *denhch’i* ‘four’, *vanhgiq* ‘Indian ice cream’, *venhdi(da’)* ‘tomorrow’, *ganhdlit* ‘cooked berries’, *xonhdzoghdl* ‘green-winged teal’ (*honhdzighudl*, Kari 1978), *-anhchin* ‘wrist, forearm’, *-anhtse* ‘nose’, and *-anhch’it* ‘nostril’. In *vanhdong* ‘this morning (past)’ and *niɬigidinghdi* ‘here and there’, *-dong* ‘past (time)’ and *-di* ‘(place) where, (time) when’ were originally suffixes.

(4) Deg Xinag vowel phonemes[9]

full	*reduced*	*full*
	ʊ	
e	ə	o
	a	

Deg Xinag is thus one of the few Athabaskan languages which lack both vowel phonemes /i u/. Another such language is Hupa (Golla 1970, Gordon 1995), with three basic quality distinctions whose realization depends on whether the vowel is short or long:

(5) Hupa vowel phonemes

e: ɪ   o: o

a: a

Vowel systems like those of Deg Xinag and Hupa run counter to those of the majority of the spoken languages of the world, which tend to have vowels which are evenly and widely dispersed, as noted by Liljencrants and Lindblom 1972 and much subsequent work. To consider just how unusual Deg Xinag is, in a typological study of the vowel systems in the UCLA Phonological Symbol Inventory Database (UPSID), a genetically controlled sample of 317 of the world's languages designed by Ian Maddieson, Disner 1984 noted only four languages in the database that lacked high vowels: Tagalog with /ɪ ə ʊ/, and Squamish, Alabama, and Amuesha with Deg Xinag-like /e a o/.

The Deg Xinag lower-high vowel /ʊ/ is restricted in distribution, mainly occurring next to uvulars (e.g. /q^{h}ʊn'/ (*qun'*) 'fire'; /tɬʊq/ (*dluq*) 'laughter'). Krauss 1962 noted that 'the Ingalik /ʊ/ appears only in context with back velars, so far as the somewhat limited data indicate…' Krauss and Golla 1981: 73, also thinking that Deg Xinag /ʊ/ occurs only next to uvulars, stated that '[Ingalik] also distinguishes PA *q^{w} from *q next to a reduced vowel,' interpreting (e.g.) [q^{h}ʊn'] as [q^{hw}ən'] and [tɬʊq] as [tɬəq^{w}]. However, as noted by Krauss 1962, the [qʊ]-as-[q^{w}ə] analysis essentially trades one limited distribution for another, as putative /q^{w}/ would only occur next to /ə/. A more serious problem for this analysis is the existence of some instances of [ʊ] next to consonants of places of articulation other than uvular. An exhaustive list of lexical items containing [ʊ] not adjacent to uvulars in Deg Xinag is given in (6):

[9] Orthographic equivalents of the vowels, where different from phonetic symbols, are /ə/ = <i> and /ʊ/ = <u>.

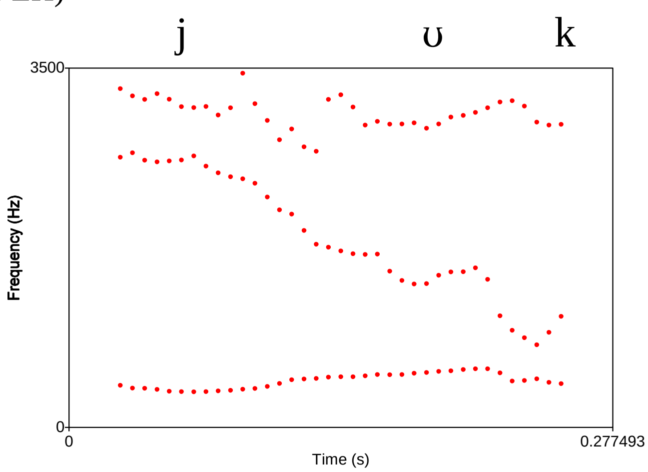
(6) Deg Xinag [ʊ] not adjacent to uvular[10]

/kʰʊla/ (*kula*)	'poor thing'
/təkʰʊl/ (*dikul*)	'gratitude'(?)
/tθək'ʊ/- (*tthik'u-*)	'uphill, into woods'
/χ-k'ʊ#O-ɬ-ʔan̥/ (*x-k'u#O-ɬ-'anh*)	'medically assist O'
/jʊk/ (*yuk*)	(listener's expression at end of story)
/pʰʊsəj/ (*pusiy*)	'cat'

Possible etymologies of the words in (6) are discussed in 3.2.

One point of investigation in the vowel system is the quality of the vowel transcribed [Y]. Impressionistically, this vowel is [Y] unless adjacent to uvulars, where the auditory impression is [ŏ]. [Y ŏ] are thus in complementary distribution, and since [ŏ] has the more limited distribution, the basic phone in this set is considered /Y/. While the uvular-adjacent allophone is investigated in the acoustic experiment described in §2, in this section I present qualitative evidence concerning /Y/e. In (7), a spectrogram of [jʊk], note the relatively high F1 of [ʊ], 543 Hz at the point where F1 and F2 are closest (reaching the target for [ʊ]), considerably higher than the 356 Hz F1 of the preceding glide [j].

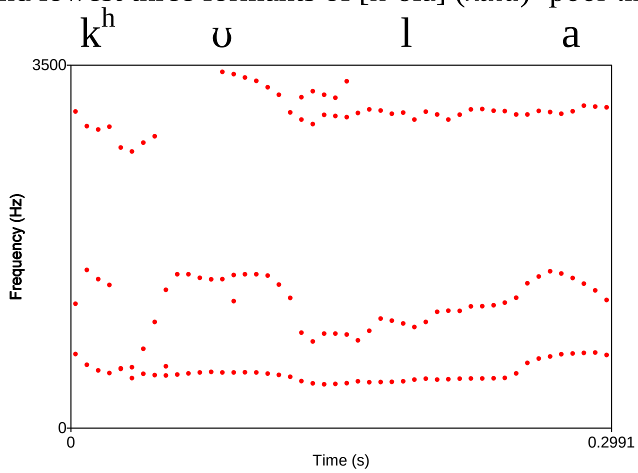
(7) Spectrogram and lowest three formants of [jʊk] (*yuk*) (listener's expression at end of story) (female speaker LH)



In (8), F1 is also not particularly low, 553 Hz (for comparison, F1 of [a] in the same token is 740 Hz).

[10]See also 1.3, where I raise the possibility that [ʊ] can also occur next to laryngeal consonants, although there predicted by rule.

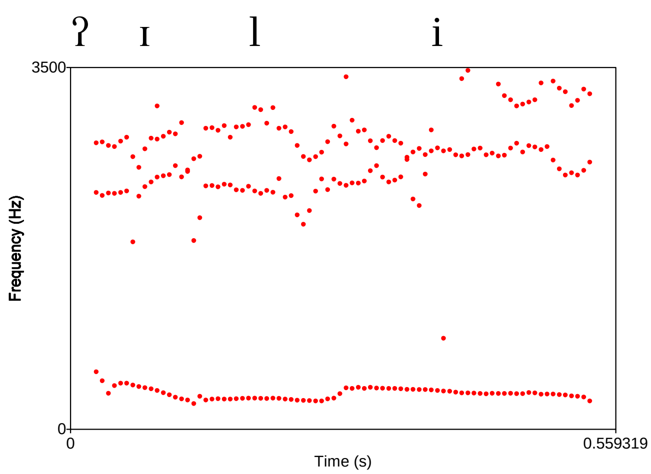
(8) Spectrogram and lowest three formants of [kʰʊla] (*kula*) 'poor thing' (female speaker LH)



In neither (7) nor (8) are F1 and F2 particularly close (in general, the closer F1 and F2, the more back the vowel quality, e.g. Ladefoged 1996), indicating centralization of [ʊ] (at least in these tokens, for this speaker).

As mentioned above, the Deg Xinag vowel phonemes were worked out by Krauss 1962, who noted that the 'system has proven a bit tricky to analyze, because of the relatively wide allophonic range of the vowels (both in quality and length)'. Krauss 1962:25c noted a particularly large set of allophones for /ə/: '[ɨ], unless /t t'/ precedes, then it is [ə], unless back velars precede or follow or /m/ follows; then it is [ʌ], unless /dž, tš, /tš', y, š, ŋ/ precedes or /ŋ, g, y/ follows; then it is [ɪ] or [ɪ^].' Impressionistically, the [ɪ^] allophone of /ə/ noted by Krauss 1962 can be even closer, even as close as [i]. In (9), note the very close F2 and F3 in the final syllable, characteristic of /i/. F2 and F3 become ever closer, even overlapping as the vowel proceeds:

(9) Spectrogram and lowest five formants of /ʔələj/ [ʔɪli] (*iliy*) 'devil'; expression of fright (female speaker ED)[11]



[11][ʔ] is predictable in word-initial position in Deg Xinag, hence omitted from phonemic representations.

1.3 Rounding Assimilation

I posit that Deg Xinag also has a phenomenon of Rounding Assimilation, whereby /ə/ and /ʊ/ are neutralized as [ʊ] when a round vowel (/ʊ/ or /o/) occurs in the following syllable and a uvular consonant intervenes:

(10) Rounding Assimilation

ə → ʊ / ___ C_{uvular} {ʊ, o}

Rounding Assimilation appears to be obligatory across an intervening uvular. The extent to which Rounding Assimilation also takes place across an intervening laryngeal is a topic of current research (Hargus in preparation). Jeff Leer (p.c.) reports that Koyukon has something like Rounding Assimilation as well, but its effects are not transcribed in the Koyukon dictionary (Jetté and Jones 2000), nor commented on in essays on Koyukon phonology (Marlow 2000, Krauss 2000).

Rounding Assimilation holds morpheme internally as well as across morpheme boundaries. In the data in (11), both vowels on either side of the uvular are round, and localization of the rounding to one or the other vowel cannot really be justified:[12]

(11) Morpheme-internal Rounding Assimilation

[jʊχʊn̥] (*yuxunh*)	'you (pl.)'
[jʊχʊdz] (*yuxudz*)	'all'
[ʊχʊtənəj] (*uxudiniy*)	'fast, quickly, early'
[tʊq^{h}ʊ]# (ð, ð) (*duqu# (dh,dh)*)	'ashore, up from water'
[jʊχoʔən] (*Yuxo'in*)	'Flat' (no known literal meaning)
[χotət], [ʊχotət] (*xodit, uxodit*)	'they (themselves)'

Some alternations induced by Rounding Assimilation are given in (12)-(13). The words in (12) all contain the progressive prefix /ʁə/-:

(12) Rounding Assimilation examples: progressive prefix

a. [ʁʊ]- before round V, intervening uvular C

[t^{h}e ʁʊ̠q^{h}oɬ] (*te ghuqoɬ*)	'he's carrying water'
[χʊtɬ ʁʊʁʊɬ] (*xutl ghughuɬ*)	'a sled is moving'

b. [ʁə]- before non-round V

[χaɬ ðəθ ʁə̠ʁaɬ] (*xaɬ dhith ghighaɬ*)	'he's packing a pack'

c. [ʁə]- before round V, intervening non-uvular or non-laryngeal C

[ʁə̠soɬ] (*ghisoɬ*)	'I'm walking'

[12]Previous transcriptions of some of the words in (11) from Kari 1978 are: *yixunh* 'you (pl.)', *yixudz* 'all'. Stress generally occurs on the final syllable in Deg Xinag polysyllables ending in a consonant (see Hargus 2005), and perhaps the source of rounding in such words was attributed to the stressed vowel.

The consonant preceding the reduced vowel of the progressive prefix is a uvular. Rounding Assimilation also occurs when the consonant before the vowel undergoing Rounding Assimilation is non-uvular. Alternations involving the unspecified object/possessive prefix /kə/- (*gi*-) are given in (13). In all forms in (13), the vowel of the second syllable is round:

(13) Rounding Assimilation examples: unspecified object/possessive prefix

a. [kʊ]- (*gu-*) before round V, intervening uvular C	
[kʊ̲qʰʊl] (*guqul*)	'there's nothing'
[kʊ̲q'ʊχ] (*quq'ux*)	'(something's) fat'
[kʊ̲ʁʊdz] (*gughudz*)	'boat rib'
[kʊ̲qʰod]~[kʊ̲qʰodl] (*guqod~quqodl*)	'small deadfall'
b. [kə]- (*gi*) before round V, intervening coronal C	
[kə̲ðʊχ] (*gidhux*)	'she's scraping something'
[kə̲son̥] (*gisonh*)	'I'm eating something'

If it turns out that Rounding Assimilation also takes place across a laryngeal consonant, then the phenomenon is significant for discussion of the distribution of [ʊ]: the surface distribution of [ʊ] would not be limited to adjacent uvular consonant.

2 An acoustic study of Deg Xinag vowel quality and quantity

2.1 Research questions

Because of the odd position of /Y/ in the Deg Xinag inventory, an acoustic study was undertaken to determine whether or not the uvular-adjacent allophone is truly a short version of /o/, as auditory impressions suggest. In order to understand the position of /Y/ relative to the other vowels of Deg Xinag, a set of narrower research questions was devised:

(14) Research questions for acoustic study

a. What are the spectral properties of the Deg Xinag vowels?
   i. Which vowels are significantly different in normalized F1 and F2?
   ii. How does an adjacent uvular consonant affect the vowel formants?
   iii. How does an adjacent retroflex consonant affect the vowel formants?
b. Which vowels are significantly different in duration?

Disner 1984:141, in discussing the three languages in UPSID which lack /i u/ (Squamish, Alabama and Amuesha) (see 1.2), stated that 'for these languages, and for Cheremis, which are compressed along one edge of the vowel space only, acoustic measurements are needed to determine whether near-maximal, or only adequate, dispersion is in effect.' Thus research question (14)a.i. is designed to confirm what all previous Deg Xinag field researchers' ears have heard: namely, that in place of /i u/ Deg Xinag has /e o/.

Justification for research question (14)a.ii. (effect of adjacent uvular consonant) is that /ʊ/ mainly occurs adjacent to a uvular consonant in DX, as discussed above, and uvulars have well-known cross-linguistic lowering and/or backing effects on vowel quality. For example, in the evolution of Witsuwit'en-Babine from Proto-Athabaskan, high vowels **i:* and **u:* lowered to [e] and [o] before a uvular (Story 1984, Hargus 2007).

Justification for research question (14)a.iii. (effect of adjacent retroflex consonant) is more complex. As noted by Minoura 1993, Minoura 1994, the Proto-Athabaskan full vowels underwent a process of 'sibilant-loss-related vowel modification' in their development in Upper Tanana. In that language **i:* and **e:* > /ea/, **a:* > /ɯː/, and **u:* > /iu/; and full nasal vowels **į:* > /įą/ and **ǫ:* > /įǫ/.[13] The change happened before sibilants, described by Minoura 1994:163-164 as the class consisting of 'θ, ð, tθ, as well as s-, ts-, š-, tš-type sounds.' The sibilants were then deleted, or neutralized to /h/ or /t/. Tuttle and Lovick 2008 proposed that 'UT vowel retraction is a generalization of retraction preceding stem-final retroflexes.' According to their historical scenario, the sibilants were all neutralized to retroflex in stem-final position in pre-Upper Tanana, with the retroflexion then responsible for the distinctive patterns of vowel modification seen in modern Upper Tanana before becoming lost. Thus, for Deg Xinag, research question (14)a.iii. investigates to what extent retroflex consonants affect vowel quality synchronically.

2.2 Method

2.2.1 Participants and recordings

Acoustic recordings were made in the field with eight adult native speakers of Deg Xinag, three male and five female. The speakers varied in age from approximately 68-80 at the time of recording. All were bilingual in English, with varying degrees of proficiency in English.

Recordings were made using either a professional CD recorder or compact flash recorder, with an AT 4041 microphone externally attached. The sampling rate at the time of recording was 44,100 Hz, later downsampled to 11,025 for analysis. Four repetitions of each token were elicited from each speaker. Sets of repetitions were recorded in random order (the same random order for each speaker).

Each target word on the vowel duration word list was embedded in a sentence context, presented to speakers using the symbols of the practical writing system. The English translation of the sentence was also included.

(15) Sentence context for vowel duration word list (in DX orthography)

chenh ______	didaghsne'	"I said ______ again"
again	I said	

Although there are some Deg Xinag publications that utilize the writing system (e.g. Kari 1978, Kari 1981, Deacon 1985, Jerue et al. 1993), only three speakers had minimal proficiency in written Deg Xinag. Some speakers could sometimes recognize the target word from the English

[13]Proto-Athabaskan is generally reconstructed without nasal vowels; see Leer 1979:14 for more discussion. There Leer notes that 'alternatively, perhaps nasalization was a common feature of PAE' [Proto-Athabaskan-Eyak]. Note also the following PA reconstructions with nasal vowels (transcribed with subscript nasal hook); e.g. **O-q'ą:ts'* 'stretch O, out, limber up O' (Leer 2006-2010: q'/54), **də-q'ų:tš'* 'be sour' (Leer 2006-2010: q'/162), **(ɬ-D)-wą:ts'* 'roll' (Leer 2006-2010: w/4), **O-u:-'į:ɬ* '(male) copulates with O' (Leer 2006-2010: '/25), **wį:ɬ* 'snare, net' (Leer 2006-2010: w/17).

translation, but others did not have strong English literacy skills. Often it was necessary to orally prompt speakers in order for them to recognize the target word.

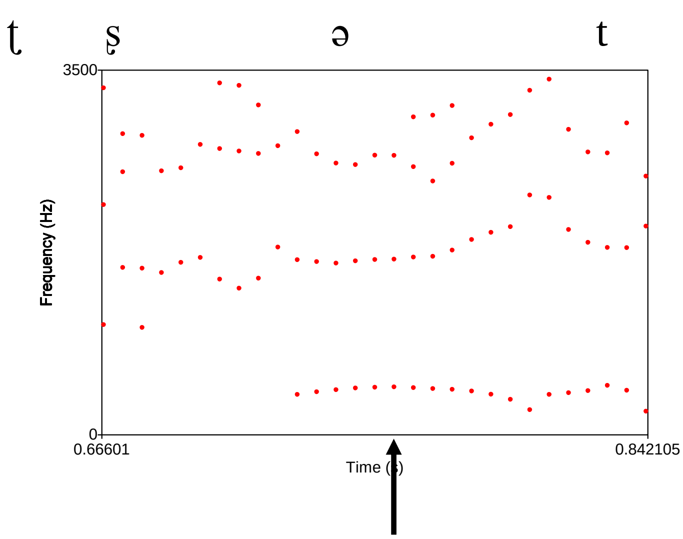
Preceding and following consonant place and manner of articulation was controlled for in the vowel duration word list. Vowels were recorded in two consonantal contexts: (a) voiceless unaspirated alveolar stop___ voiceless unaspirated alveolar stop or affricate, and (b) voiceless unaspirated uvular stop ___ voiceless unaspirated alveolar stop or affricate. One or two lexical items were selected for each context. The word lists for each context are given in the respective results sections below.

The words on the vowel quality word list were recorded in isolation, except for some words taken from the vowel duration word list. Vowels were recorded in five consonantal contexts: alveolar ___ alveolar, alveolar ___retroflex, retroflex ___alveolar, uvular ___ alveolar, alveolar ___ uvular. Like the vowel duration study, the words on the vowel quality word list were presented to speakers in written form along with their English translations. Oral prompting was utilized as needed.

2.2.2 Acoustic analysis

Measures of the lowest four formants of vowels were made using Praat (version 4.3.27). Maximum Formant settings were 5000 Hz for men and 5500 Hz for women. Vowels were measured at the steady-state point of the vowel (if there was one), where F1 and F2 had reached their points of maximal displacement (if they did), often but not always at the vowel's midpoint. In (16), the measurement point of the vowel in this token is indicated by the arrow. This is the point where F1 is at its highest. In this token, F2, on the other hand, does not have such a clear target but rises steadily across the vowel:

(16) Sample spectrogram and lowest three formants of /χaθʈʂət/ (*xathdrit*) 'they're lying down', showing measurement point in [ə] (HM, a female speaker)



In this token, measured F1 is 452 Hz and F2 1708.

Vowel duration measures were made using Multi-Speech 2.5. First tags were placed at the onset and offset of F2, and saved with each sound file. Tags helped ensure consistency of measurement points across the data set. After tags were placed in all tokens for a particular speaker, duration was then measured between the tags.

2.2.3 Statistical analysis

Two inferential statistical tests were used. The first was repeated measures ANOVA. In the vowel duration studies, the independent variable was Vowel (phoneme), and the dependent variable was each speaker's mean vowel duration. In the vowel quality studies, the independent variable was also Vowel (phoneme), and the dependent variable was each speaker's mean log-normalized F1 and F2 (Nearey 1978, Nearey 1989).[14] Post hoc analysis was performed with the Bonferroni/Dunn test, with alpha level set to .05.

2.3 Results: Spectral properties of vowels

In this section, sample vowel plots, not log-normalized, were generated with PlotFormants. These graphs show Bark-scaled F2 on the horizontal axis and F1 on the vertical axis. The large symbol represents the mean F2 and F1 for that vowel, and the ovals represent two standard deviations. These vowel plots are included here for illustrative purposes only, as they approximate the look of traditional vowel charts. They are all from the same female speaker. Vowel plots for the other speakers measured are given in the appendix (§6).

2.3.1 Alveolar ___ alveolar

The word list for the vowels measured in this context are given in (17):

(17) Vowels in alveolar___alveolar context

a	/nta̲taʔ/ (*nda̲da'*)	'when (in the future)?'
	/ntadz/ (*ndadz*)	'how'
e	/ℜeɢəte̲d/ (*ℜeggide̲d*)	'eel'
	/kokəte̲t/ (*gogide̲t*)	(listener's response to *ade'* 'hello')
ə	/taℜtədð/ (*daℜdiddh*)	'red-necked grebe'
	/vətaʁtɬtə̲ts/ (*vidaghtldits*)	'I bit it'
o	/ŋətot/ (*ngidot*)	'downriver there'
	/ŋətodz/ (*ngidodz*)	'from downriver'

In the sample vowel plot in (18), note the relatively low F1 and high F2 for /ə/, which gives the auditory impression of an [ɪ]-like vowel in this context, due to the high F2 of the surrounding coronal consonants. Also note the relatively front position of /a/ relative to /o/ for this speaker.

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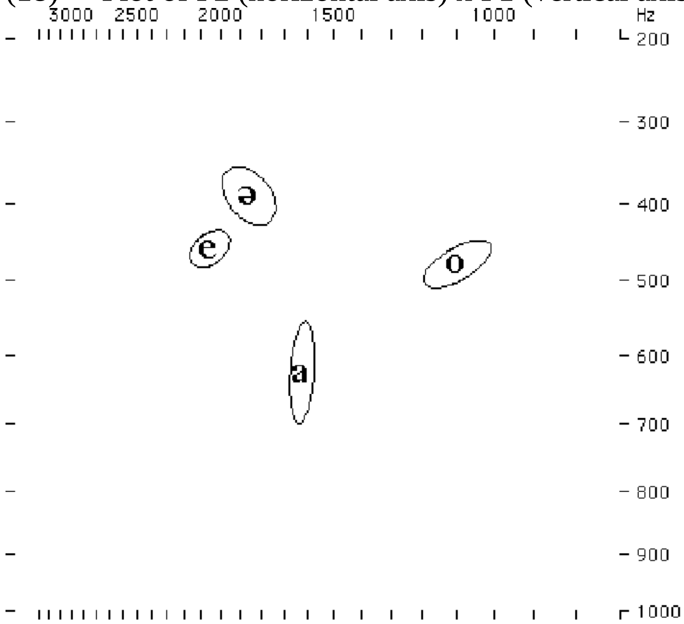
[14] See Shirai 2004 for step-by-step description of the log-normalization technique.

(18) Plot of F2 (horizontal axis) x F1 (vertical axis) / alveolar___alveolar (HM)



For vowel plots of other speakers in this context, see 6.1.

The male speakers' mean F1 and F2 in this context are given in (19). Corresponding values for female speakers are shown in (20).

(19) Mean F1 and F2 (male speakers)

	F1				F2			
	a	e	ə	o	a	e	ə	o
JD	679	422	381	421	1487	1812	1656	1029
PA	728	480	416	476	1283	1762	1646	860
RD	545	456	422	457	1282	1833	1736	1002

(20) Mean F1 and F2 (female speakers)

	F1				F2			
	a	e	ə	o	a	e	ə	o
AJ	851	421	386	543	1816	2175	2058	1058
ED	788	509	440	594	1625	2374	2312	1094
HM	626	459	391	478	1624	2056	1858	1100
KH	796	541	471	459	1497	1822	1949	997
LH	829	564	443	529	1592	2152	2102	1218

Repeated measures ANOVA indicated significant differences in both normalized F1 ($F[3,21] = 56.397$, $p < .0001$) and normalized F2 ($F[3,21] = 208.493$, $p < .0001$). Post hoc analysis revealed that all vowel pairs except [e o] were significantly different in normalized F1. All vowel pairs except [e ə] were significantly different in normalized F2. Post hoc analysis thus indicates that the vowels divide into three vowel heights (low, [a]; mid, [e o]; lower-high, [ə]) and three degrees of backness (front, [e ə]; central, [a]; back, [o]) in this context, more or less as expected from auditory impressions.

2.3.2 Retroflex___alveolar

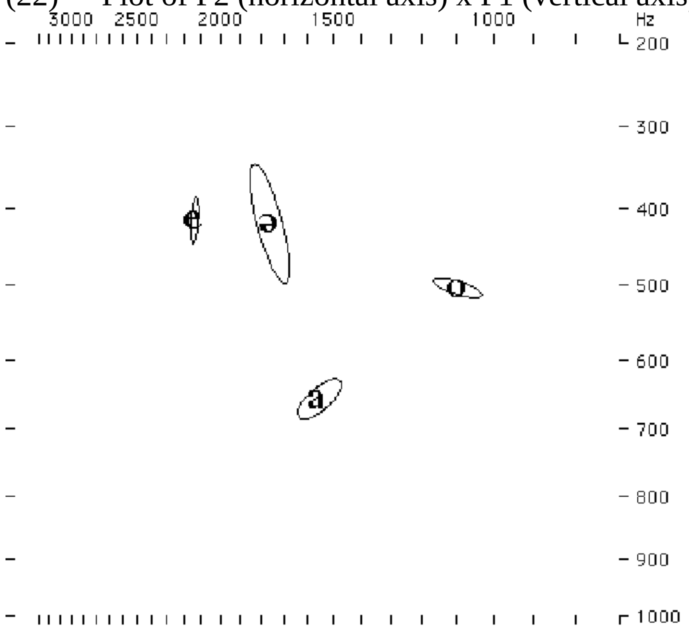
The word list for the vowels measured in this context is given in (21):

(21) Vowels in retroflex___alveolar context

a	/ʈ͜ʂʰaℜtθ’et/ (*traℜtth’et*) [15]	‘kashim’
e	/ʈ͜ʂed/ (*dred*)	‘seldom’
ə	/χaθʈ͜ʂət/ (*xathdrɨt*)	‘they’re lying down’
o	/vəʈ͜ʂod/ (*vɨdrod*)	‘his foreleg, shin’[16]

In the representative vowel plot in (22), note the absence of the fronting and raising of /ə/ for this speaker in this context, unlike (18), with preceding alveolar consonant:

(22) Plot of F2 (horizontal axis) x F1 (vertical axis) / retroflex___alveolar (HM)



Plots of the other speakers in this context are provided in 6.2.

The male speakers’ mean F1 and F2 in this context are given in (23). Corresponding values for (female speakers) are shown in (24).

[15] Some speakers pronounced this word *sraℜtth’et*.

[16] *Nithidrok* ‘they (granular objects) are’ was substituted for some speakers. This choice of lexical item was not ideal, since it ended in a velar rather than alveolar consonant.

(23) Mean F1 and F2 (male speakers)

	F1				F2			
	a	e	ə	o	a	e	ə	o
JD	633	413	446	491	1444	1824	1655	999
PA	704	547	487	503	1298	1520	1530	942
RD	587	326	417	390	1401	1614	1443	853

(24) Mean F1 and F2 (female speakers)

	F1				F2			
	a	e	ə	o	a	e	ə	o
AJ	680	421	418	376	1207	2016	1368	977
ED	805	557	461	621	1530	2275	2164	1084
HM	656	416	421	503	1554	2138	1763	1096
KH	761	575	457	567	1435	2000	1757	1084
LH	818	494	385	530	1535	2068	2098	1123

Repeated measures ANOVA indicated significant differences in both normalized F1 ($F[3,21] = 38.387$, $p < .0001$) and normalized F2 ($F[3,21] = 109.193$, $p < .0001$). Post hoc analysis revealed that all vowel pairs were significantly different in normalized F1 except [e o], [e ə], and [o ə]. All vowel pairs were significantly different in normalized F2. Post hoc analysis thus indicates that the vowels divide into two vowel heights (low, [a]; mid, [e o ə]) and four degrees of backness (front, [e]; central-front, [ə]; central-back, [a]; back, [o]).

2.3.3 Alveolar___retroflex

The word list for the vowels measured in this context is given in (25):

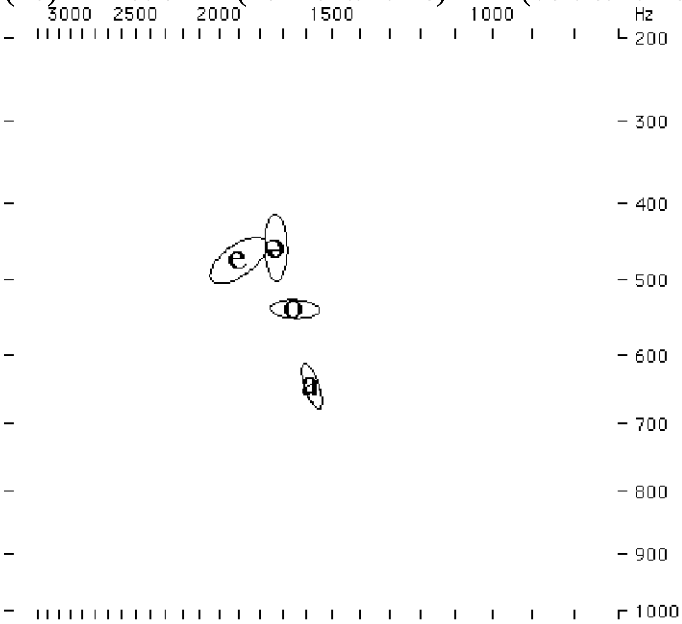
(25) Vowels in alveolar___ retroflex context

a	/vətaɖʐ̺/ (*vɨdadr*)	‘his younger sister’
e	/ɼeʈʂ̺’aʔ/ (*ɼetr’a’*)	‘female dog’
ə	/ðələʈʂ̺/ (*dhilɨtr*)	‘he urinated’
o	/vəjoʈʂ̺’aʔ/ (*vɨyotr’a’*)	‘his daughter-in-law’[17]

In the representative vowel plot in (26), note the centralization of all vowels for this speaker in this context:

[17]*gilotr’ey* ‘peeled spruce bark’ was substituted for some speakers.

(26) Plot of F2 (horizontal axis) x F1 (vertical axis) / alveolar___retroflex (HM)



Plots of the other speakers measured in this context are provided in 6.3.

The male speakers' mean F1 and F2 in this context are given in (27). Corresponding values for female speakers are shown in (28).

(27) Mean F1 and F2 (male speakers)

	F1				F2			
	a	e	ə	o	a	e	ə	o
JD	660	365	416	463	1374	1809	1705	1129
PA	665	363	509	513	1249	1789	1601	972
RD	582	524	388	438	1054	1698	1599	1274

(28) Mean F1 and F2 (female speakers)

	F1				F2			
	a	e	ə	o	a	e	ə	o
AJ	817	468	367	402	1109	1868	1593	1193
ED	791	624	504	583	1391	2119	2017	1296
HM	645	474	458	538	1579	1903	1728	1649
KH	817	511	597	561	1491	1863	1623	1158
LH	647	419	470	454	1321	1908	1863	1272

Repeated measures ANOVA indicated significant differences in both normalized F1 ($F[3,21] = 21.4937$, $p < .0001$) and normalized F2 ($F[3,21] = 39.287$, $p < .0001$). Post hoc analysis revealed that all vowel pairs were significantly different in normalized F1 except [e o], [e ə], and [o ə]. All vowel pairs were significantly different in normalized F2 except [a o] and [e ə]. Post hoc analysis thus indicates that the vowels divide into two heights (low, [a]; mid, [e o ə]) and two degrees of backness (front-central, [e ə]; back-central, [a o]).

2.3.4 Uvular___alveolar

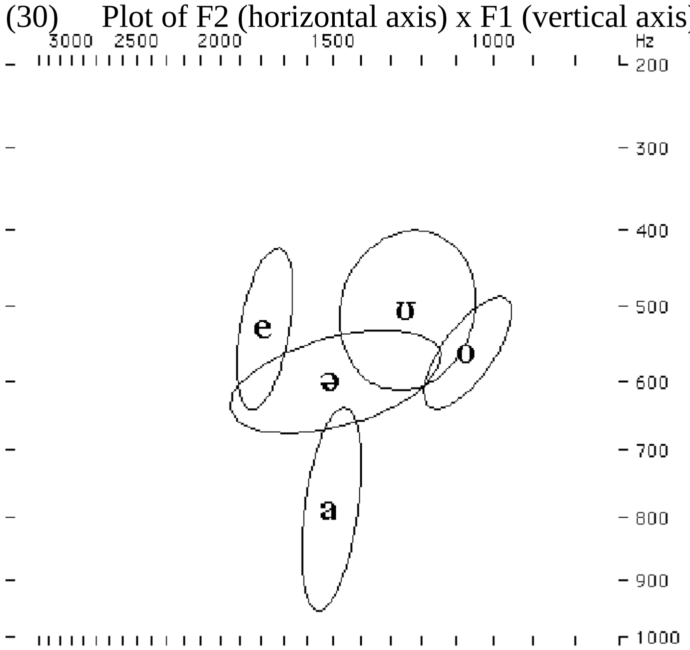
The word list for the vowels measured in this context is given in (29):

(29) Vowels in uvular___ alveolar context

a	/vav aʁsqʰat/ (*vav aghsqat*)	'I bought food'
	/χaℜ ðəθ/ (*xaℜ dhith*)	'pack sack'
e	/jəℜqeθ/ (*yiℜggeth*)	'he's eating it (crunchy object)'
	/χəʂʁed/ (*xisrghed*)	'rosehip'
ə	/sədəɬqʰə̲t/, /sədəŋəɬqʰə̲t/ (*sidiɬqə̲t, sidiŋiɬqi̲t*)	'ask me'
	/ŋəℜʁə̲tɬ/ (*ngiℜghitl*)	'club it'
o	/nəkəχənəʁeqʰot(l)/ (*nigixinigheqot(l)*)	'(the house) collapsed'
	/qoℜ jan' tətɬʔaṋ/ (*ggoℜ yan' ditl-'anh*)	'I'm walking' (lit. 'I'm just doing walking')
ʊ	/vankəŋəℜqʰʊt/ (*van-gəŋəℜqʊt*)	'patch it'
	/χʊtɬ/ (*xutl*)	'sled'

In the representative vowel plot in (30), note the more compressed vowel space and greater variability for each vowel relative to the alveolar___alveolar context. Also note here the relatively high F1 for /ə/, resulting in an [ʌ]-like vowel, as well as the partial spectral overlap of /ʊ/ with /o/ and /ə/.

(30) Plot of F2 (horizontal axis) x F1 (vertical axis) / uvular___ alveolar (HM)



Plots of the other speakers are provided in 6.4, where it can be seen that all speakers have more variable realizations of the vowels in this context.

The male speakers' mean F1 and F2 in this context are given in (31). Corresponding values for female speakers are shown in (32).

(31) Mean F1 and F2 (male speakers)

	F1					F2				
	a	e	ə	o	ʊ	a	e	ə	o	ʊ
JD	702	479	617	463	494	1392	1831	1521	878	1079
PA	790	628	663	558	598	1314	1628	1315	949	1058
RD	724	518	609	502	514	1464	1673	1418	929	1065

(32) Mean F1 and F2 (female speakers)

	F1					F2				
	a	e	ə	o	ʊ	a	e	ə	o	ʊ
AJ	687	618	512	498	555	1230	1767	1153	900	1086
ED	860	605	778	651	666	1469	2136	1579	1082	1248
HM	790	530	602	562	505	1508	1784	1506	1070	1250
KH	843	624	813	638	660	1424	1978	1406	1069	1211
LH	863	622	896	675	732	1438	2205	1532	1141	1360

Repeated measures ANOVA indicated significant differences in both normalized F1 ($F[4,28] = 29.728$, $p < .0001$) and normalized F2 ($F[4,28] = 135.898$, $p < .0001$). Post hoc analysis revealed that all vowel pairs were significantly different in normalized F1 except [e o], [e Y], and [o Y] (note that [Y] had significantly lower F1 than [ə]). All vowel pairs were significantly different in normalized F2 except [a ə]. Post hoc analysis thus indicates that the vowels divide into three heights (higher-mid [Y]; lower-mid [ə]; and low, [a]) and four degrees of backness (front, [e]; central, [a ə]; central-back, [Y]; back, [o]).

2.3.5 Alveolar___uvular

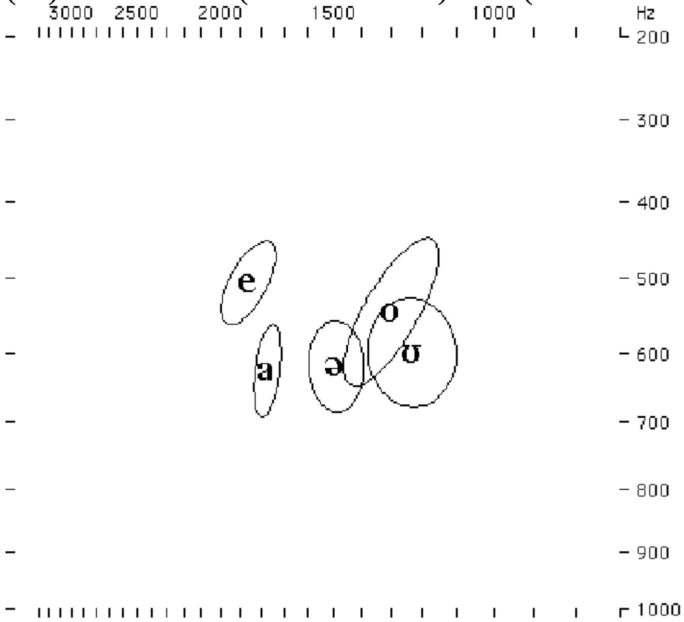
The word list for the vowels measured in this context is given in (33):

(33) Vowels in alveolar___ uvular context

a	/tɬ^{h}aɢ/ (*tlagg*)	'no-good'
	/t^{h}oʧ^{h}aɢ/ (*tochagg*)	'enclosed slough'
e	/ℜeqoj/ (*ℜeggoy*)	'puppy'
	/ʔeq/ (*eq*)	'fog'
ə	/kəℜəɢ/ (*giℜigg*)	'one'
	/ŋəjəɢ/ (*ngiyigg*)	'down, inside'
o	/q^{h}ʊθ təseloq/ (*quth diseloq*)	'I have a cold'
	/vəʧ^{h}oq/ (*vichoq*)	'his rib'
ʊ	/tətɬ^{h}ʊq/ (*ditluq*)	'it's baggy'
	/təʧ'ʊq/ (*dich'uq*)	'it's sharp (quill-like)'

In the representative vowel plot in (34), note the relatively high F1 of /ə/ (again, [ʌ]-like) for HM, as well as the relatively high F1 of /ʊ/ and spectral overlap with /o/.

(34) Plot of F2 (horizontal axis) x F1 (vertical axis) / alveolar___uvular (HM)



Plots of the other speakers are provided in 6.5. Like the uvular__alveolar context, all speakers' vowels tend to have a relatively high degree of variability in the alveolar___uvular context.

The male speakers' mean F1 and F2 in this context are given in (35). Corresponding values for female speakers are shown in (36).

(35) Mean F1 and F2 (male speakers)

	F1					F2				
	a	e	ə	o	ʊ	a	e	ə	o	ʊ
JD	612	386	620	483	458	1476	1825	1438	1102	1002
PA	734	622	666	535	512	1392	1534	1240	935	937
RD	571	495	640	476	511	1242	1625	1254	975	1013

(36) Mean F1 and F2 (female speakers)

	F1					F2				
	a	e	ə	o	ʊ	a	e	ə	o	ʊ
AJ	842	612	676	509	624	1532	1975	1242	1036	1089
ED	753	606	751	628	641	1833	2238	1553	1154	1183
HM	626	505	619	545	600	1773	1862	1492	1302	1235
KH	828	611	807	638	683	1641	1834	1317	1180	1197
LH	821	612	812	610	591	1653	1927	1432	1174	1236

Repeated measures ANOVA indicated significant differences in both normalized F1 ($F[4,28] = 23.900$, $p < .0001$) and normalized F2 ($F[4,28] = 123.625$, $p < .0001$). Post hoc analysis revealed that of the ten possible vowel pairs, all were significantly different in normalized F1 except [a ə], [e o], [e Y], and [o Y]. All vowel pairs were significantly different in normalized F2 except [o Y]. Post hoc analysis thus indicates that in this context the vowels divide into two heights (mid, [e o Y]; and low, [a ə]) and four degrees of backness (front, [e]; central, [a]; central-back, [ə]; back, [o Y]).

2.3.6 Spectral properties summary

The spectral trends in the Deg Xinag vowels measured here are summarized in (37), where 'G1' represents normalized F1, 'G2' represents normalized F2, and '=' means 'not significantly different':[18]

(37) Lack of significant differences in normalized F1 or F2 for vowels in different consonantal contexts

	__alveolar	__retroflex	__uvular
alveolar__	G1: e = o G2: e = ə	G1: e = o, e = ə, ə = o G2: a = o, e = ə	G1: a = ə, e = o, e = Y, o = Y G2: o = Y
retroflex__	G1: e = o, e = ə, ə = o		
uvular__	G1: e = o, e = Y, o = Y G2: a = ə		

The fronting and raising of /ə/ when surrounded by alveolar consonants is absent when either the preceding or following consonant is retroflex. As seen above, all vowels are more centralized when adjacent to a retroflex, particularly before. If vocalic allophones of pre-Upper Tanana were similarly centralized before a retroflex, this could have indeed paved the way for the centralized diphthongs seen in that language according to the historical scenario suggested by Tuttle and Lovick 2008.

When adjacent to a uvular, /ə/ approaches /a/ in quality in two respects. Before a uvular, /ə/ is a low vowel, in fact not differing in F1 from /a/, and after a uvular, /ə/ does not differ in F2 from /a/. /Y/ does not differ in F1 from mid vowels /e o/ when preceded or followed by a uvular consonant.[19] From this phenomenon too it is easy to see the seeds of future phonemic lowering of vowels when adjacent to, especially before, uvulars in languages like Witsuwit'en.

It can also be seen from (37) that the effect of a following consonant on vowel quality is greater than that of a preceding consonant. There are fewer significant differences <u>before</u>

[18] E.g. 'G1: e = o' means '/e/ and /o/ do not differ in normalized F1'.

[19] Compare LH's [Y] adjacent to velar [k] above in (7) and (8) at 543 and 553 Hz with her averages adjacent to a uvular: 591 Hz before a uvular and 732 Hz after uvular. For LH, [Y] actually exhibits more lowering after a uvular than before. The pre-uvular lowering of [Y] does not make this vowel much lower than her [Y] in non-uvular contexts.

retroflex consonants than after, with no significant differences in normalized F1 or F2 for /e ə/. There are also fewer significant differences before uvular consonants than after, in particular, no significant differences in normalized F1 or F2 for /o ʊ/, confirming auditory impressions. These vowel pairs apparently differ only in duration in these contexts.

2.4 Results: Vowel duration

In this section, duration means for each vowel are the eight-speaker average of each speaker's mean duration for that vowel. In the tables, the number in parentheses represents one standard deviation. In bar graphs, error bars represent one standard deviation.

2.4.1 Alveolar ___alveolar

Recall that in this context, four vowels are attested in Deg Xinag. The word list for the vowels measured in this context is given in (38):

(38) Alveolar___alveolar vowel duration word list

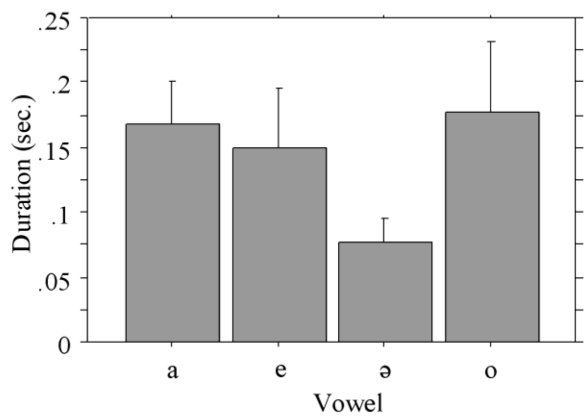
a	/tθ'aχ naθta̱tθ/ (*tth'ax nathda̱tth*)	'she spun thread'
e	/kokətet/ (*gogidet*)	(listener's response to *ade'* 'hello')
ə	/taℜtətθ/ (*daℜditth*)	'he's shivering'
o	/qʰYn' ətaℜtotθ/ (*qun' idaℜdotth*)	'the fire is crackling'[20]

Duration measures for the vowels in this context are provided in numeric form in (39) and in graphic form in (40):

(39) Mean duration in seconds of four contrasting vowels/alveolar___alveolar (data averaged across 8 speakers)

a	e	ə	o
.168 (.0154)	.150 (.0278)	.077 (.0080)	.176 (.0140)

(40) Mean duration in seconds of four contrasting vowels/alveolar___alveolar (data averaged across 8 speakers)



[20]Or *genodotth* 'black hornet', for speakers who did not know *qun' idaℜdotth*.

Repeated measures ANOVA revealed significant differences in length ($F[7,21] = 21.455$, $p < .0001$) among the four vowels. Post hoc analysis indicated that /ə/ was significantly shorter than each of /e o a/ ($p < .0001$), while /e o a/ did not differ significantly in length from each other. /ə/ thus has roughly half the duration of /a e o/.

2.4.2 Uvular ___alveolar

The word list for the five vowels measured in this context is given in (41):

(41) Uvular___alveolar vowel duration word list

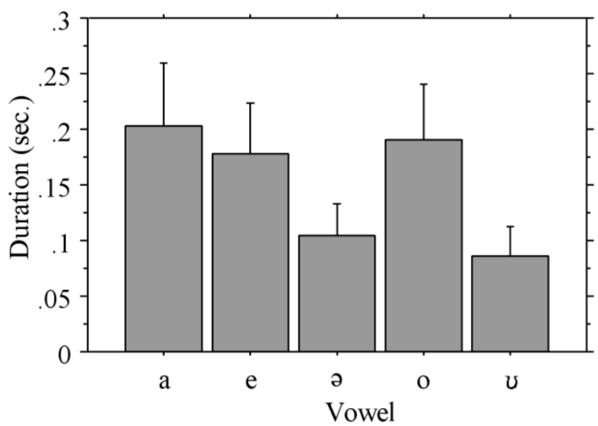
a	[jənəℜqats] (*yiniℜggats*)	'he stared at him'
e	[vəqetɬ] (*viggetl*)	'its detached skin, inner skin scrapings'
ə	[təqətT] (*diggitth*)	'it (tree) is twisted'
o	[t^hətəlqots] (*tidilggots*)	'it sank'
Y	[jət^hoqYt] (*yitoggut*)	'he'll stab it (once)'

Duration measures for the five vowels which occur in this context are provided in numeric form in (42) and in graphic form in (43):

(42) Mean duration in seconds of four contrasting vowels/uvular___alveolar (data averaged across 8 speakers)

a	e	ə	o	Y
.203 (.0169)	.178 (.0195)	.105 (.0127)	.191 (.0089)	.088 (.0108)

(43) Mean duration in seconds of five contrasting vowels/uvular___alveolar (data averaged across 8 speakers)



Repeated measures ANOVA revealed significant differences in length ($F[7,28] = 34.633$, $p < .0001$) among the vowels in this context. Post hoc analysis indicated that each of /ə Y/ is significantly shorter than each of /e o a/ ($p < .0001$ for each pair of vowels), whereas /e o a/ do not differ significantly in length from each other, nor do /ə Y/ differ significantly in length from each other.

2.5 Summary of acoustic study

As confirmed by acoustic analysis, the Deg Xinag vowel system consists of two short vowels, traditionally transcribed /ə ʊ/, and three long vowels, /e o a/. Uvulars have the most pronounced lowering and/or backing effects on the two short vowels in the system. As seen in 2.3.5, /ʊ/ and /o/ do not differ in F1 or F2 before a uvular.

3 The evolution of the Deg Xinag vowel system[21]

(44) contains the Proto-Athabaskan (PA) vowel system, consisting of four full vowels and three reduced vowels, as reconstructed by Krauss 1964 (and further annotated by Krauss, p.c.):

(44) Proto-Athabaskan vowels

full	*reduced*	*full*
*i:		*u:
	*ʊ	
	*ə	
	*ɑ$^{<\wedge}$ ("α")	
*ɛ:/æ: ("e:")		*ɑ:/ɔ: ("a:")

Reflexes in daughter languages indicate that the PA vowel usually reconstructed as **e:* varied between lower mid and low front, [ɛ:]~[æ:], and the PA vowel usually reconstructed as **a:* was low, back and perhaps round, [ɑ:]~[ɔ:].[22] Interestingly, the "square" arrangement of four full vowels found in PA is in fact the most common four-vowel inventory, as noted by Lindblom 1975 (/i a u/ plus a front vowel). Disner 1984: 141 notes three vowel systems in UPSID which are similar to that of the PA full vowels (Shasta, Paez and Moxo).

The PA vowel reconstructed as **α* was a higher and more centralized vowel than **a:* (as well as shorter). The PA vowel reconstructed as **ə* was central-front, intermediate in quality between [ɪ] and [ɛ].

3.1 Development of PA full vowels

Leer 1979(?) notes that the PA full vowels underwent a "counter-clockwise rotation" in Deg Xinag. Apparently the first stage in this rotation was the merger of **i:* and **u:* as **i:*,[23] then

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[21]This section owes much to discussions with Michael Krauss. For the most part in this section, DX is transcribed using the symbols of the practical orthography, as these differ less from the way in which PA is currently transcribed.

[22]Perhaps **ɑ:/ɒ:* would then be a better choice of narrow phonetic symbols for *"a:".

[23]Krauss 1962:25c noted that 'the most important thing in the development of this system is the forward shift and merger of /*u/ with /*i/.'

their subsequent lowering to /e:/. These sound changes shown in (45)-(46). They have few exceptions.[24]

(45) PA *i: > DX /e/

**O-ə=də…-li:* ‘sing O’ (Leer 2006-2010: ɬ/82)	*g-d-le*
**P-ni:dž^{r}əd* ‘middle, center’ (Leer 2006-2010: n/61)	*-nedr*
**tši:tɬ’* ‘fallen snow, snow on the ground’ (A), ‘blowing snow, drifting snow, snowdrift’ (BETS) (Leer 2006-2010: tš^{r}/99)	*tsetl* ‘snowdrift’
**i̓:-* perfective negative (Leer 2006-2010: 0/h 11)	*e- ~ ə-*

(46) PA *u: > DX /e/

**ɬu:t’* ‘scab’, (AS also) ‘sore, ulcer’ (Leer 2006-2010: ɬ/97)	*ɬet*
**nu:* ‘island (esp. river island)’ (Leer 2006-2010: n/63)	*ne*
**-tšų:* ‘maternal grandmother’ (Leer 2006-2010: tš(^{r}) 113)	*-tse* ‘grandmother’
**k’^{y}əyu:yi:* ‘something else, different’ (Leer 1987, p.c.)	*giye~giyey* ‘another, different’

In prefixes, **u:* > Deg Xinag /e/, with further evolution to /ə/ within paradigms (like the perfective negative prefix listed in (45)): e.g. PA **O-u:-təm’* ‘hold O’ (Leer 2006-2010: t/51) > DX *yeting’* ‘he’s holding it’, *isting’* ‘I’m holding it’.

Perhaps the shift of **u:* > **i:* was triggered by the large numbers of coronal consonants in pre-DX (which would have increased following the split of the **k^{y}* series to /k/ and /ʧ/). Coronal consonants have an F2-raising effect on [u], thereby fronting and increasing the similarity of [u] to [i] (Ohala 1981). **u:* > *i:* also occurred in Dogrib (Howren 1979), but in that language there may have also been some sort of “systemic” pressure possibly due to the (prior?) shift of **ə* > /o/, yielding the Dogrib vowel system /i e a o/.

The result of the fronting of **u:* > **i:* would have been the pre-Deg Xinag vowel system in (47):

(47) Pre-Deg Xinag vowels, after PA **u:*, **i:* > **i:*

full	*reduced*	*full*
*i:		
	*ʊ	
	*ə	
	*ɑ<^ (“α”)	
*ɛ:/æ: (“e:”)		*ɑ:/ɔ: (“a:”)

Krauss 1962 and Kari 1977 note similarities in the historical development of the DX and Dena’ina vowel systems. As summarized by Krauss and Golla 1981: 73, the Deg Xinag vowel system ‘has developed essentially’ as in Dena’ina (a.k.a. Tanaina). In that language, ‘the main feature distinguishing Tanaina from Ahtna, but which Tanaina shares with Ingalik, is the reduction of the vowel system from seven to four vowels (a system resembling that of Yupik

[24] **u:* > /o/ occurs in **nu:n-i* ‘porcupine’ (Leer 2006-2010: n/64) > *none* (K) ‘porcupine’ (Kari 1978).

Eskimo, perhaps not by coincidence): PA *i* and *u* both > *i* [ɪ], *e* > *a*, *a* > *u* [ʊ], and the three PA reduced vowels *ə, *ɑ, *ʊ all > ə.' The Yup'ik vowel system referred to by Krauss and Golla is given in (48):

(48) Yup'ik vowels (e.g. Jacobson 1984)

i: i		u: u
	ə	
	a: a	

The merger of *u:* and *i:* as *i:* created an asymmetry in the pre-Deg Xinag vowel system, as seen in (47), and it is tempting to view the subsequent shift of *i:*, *e:* and *a:* to their current Deg Xinag positions as a way of resolving the asymmetry. However, Maddieson 1984: 124-125, analyzing vowel patterns in the 317 languages in UPSID, notes that:

> …high front vowels are more frequent than high back vowels…The 3 vowels at the corners of the conventional vowel triangle, /i, a, u/, are the most widespread, but note that there are 24 fewer languages with /u/ than with /i/. These three vowels might be expected to be equally favored, because they each lie at an acoustic extreme. The low vowel /a/ has the highest first formant, /i/ and /u/ have the lowest first formant but /i/ has the highest second (and third) formant, whereas /u/ has the lowest second formant. However, a contributory factor to the relative disfavoring of /u/ may be the lower amplitude typical of /u/.

Athabaskan systems with /i/ but not /u/ (Dogrib, Navajo) are thus in accord with Maddieson's typological observations. Moreover, Disner 1984: 142 notes that /u/ is even more likely to be absent from vowel systems than the mid vowels /e o/.

The rotation of *i:*, *e:* and *a:* in the pre-Deg Xinag vowel space might not actually have involved great acoustic distance, if the pre-Deg Xinag merged *i:* was lower-high, as in Dena'ina, and also given the hypothesized low to lower-mid positions of *ɛ:/æ: and *a:/ɔ:* at this stage. (Recall from 2.3.1 that in the coronal___coronal context DX /a/ is not very back.)

(49) Pre-DX vowels, following hypothesized lowering of *i:* to *ɪ:*

full	*reduced*	*full*
*ɪ:	*ʊ *ə *ɑ$^{<\wedge}$	
*ɛ:/æ:		*ɑ:/ɔ:

Examples of the DX reflexes of _*i:_ and _*u:_ were given above in (45). Eventually *_ɛ:/æ:_ (“*_e:_”) > DX /a/ and *_ɑ:/ɔ:_ (“*_a:_”) > DX /o/, as shown in (50) and (51), respectively. There are few exceptions to these sound changes.[25]

(50) PA *_e:_ > DX /a/

*P-e:(s)-dən (Leer 2006-2010: 0/H 10), _-e:-dən_ (Leer 2006-2010: d/32) ‘without O’	_-adi_
_*(D-)le:ŋ_^{y} ‘(meat) is fresh; (_də-_ stick: (tree, wood) is green)’ (Leer 2006-2010: ɬ/72)	_didilang_ ‘green wood’
_*-de:tɬ’_ ‘several go’ (Leer 2006-2010: d/52)	_-datl_
_*še:-qe:-yu_ (also _*š(ə)-qe:-yu)_ ‘children’ (Leer 2006-2010: q/123)	_sraqay_
*_ɬ-D-ẏe:_ ‘be greasy, oily’ (Leer 2006-2010: x̣/169)	_l-ghanh_ ‘be fat’

(51) PA *_a:_ > DX /o/

PA *_a_	DX /o/
_*-a:d-e:_ ‘older sister’ (Leer 2006-2010: 0/H 7)	_-oda_
*_k_^{y}_a:n_ ‘rain’ (Leer 2006-2010: k^{y}/11)	_chonh_
_*O-q’a:_ ‘grind O, file O, sharpen O by grinding or filing’ (Leer 2006-2010: 9)	_ni#O-q’o_

Regardless of whether or not symmetry was a driving force or not, the result of the counter-clockwise shift of the full vowels would have been a more symmetrical vowel system than that prior to the shift. As Krauss 1962 put it, ‘unlike Tanaina…phonetic symmetry [in Ingalik] has been retained instead by the opening of /i/…’[26]

3.2 Development of PA reduced vowels

With few exceptions, PA *_ə_ > DX /ə/, in both stems and prefixes, as noted by Krauss and Golla 1981:72.[27]

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[25] _*a:_ > /e/ in _*O-D-na:ŋ_^{y} ‘drink O’ (Leer 2006-2010: n/9) > _O-D-nenh_. _*a:_ > /a/ in *_ɬ-D-wa:_^{y} ‘be gray, off-white (incl. tan color)’ (Leer 2006-2010: w/6) > _vay_ ‘white’; and _*a:_ > /a/~/o/ in *_ŋ_^{y}_a:n’_ ‘across, on the other side (of the water)’ (Leer 1989) > _-ngan_ ‘across’ but *_ŋ_^{y}_a:n’-tš’ən_ ‘(from) across’ (Leer 1989) > _-ngodz_.

[26] It is not at all clear, however, that phonological symmetry (as opposed to acoustic/perceptual distance) is a driving force in the evolution of vowel systems, given historically stable systems with gaps, as noted by Disner 1984 and Blevins 2004.

[27] *_ə_ > /a/ in *_x̣ə̉ɬ-tš’ən’_ ‘evening, dusk’ (Leer 2006-2010: tš’$^{(r)}$/31, x̣/143) > _xaɬts’in’_ ‘evening,’ PA *_tsəɬəx_^{y} ‘ground squirrel’ (Leer 2006-2010: ɬ/51) > _tsalik_, and possibly _*x̣ənəg_^{y} ‘word’ (Story 1984) > _xinag_ ‘word, language’ (but cf. Leer 2006-2010: 0/h 5 _*qə-(nə-)(h)a:_^{y} _(A-g_^{y}_)_ ‘speak (forcefully)’. *_ə_ > *_ʊ_ (> /o/) in *_tɬ’əɣ̇əx_^{y}, *_tɬ’əɣ̇əs_ ‘left side/hand’ (Leer 2006-2010: tɬ’/35) > _tl’oghs-_, and *_g_^{y}_ə̉:g_^{y}_e:_ ‘berry’ (Leer 2006-2010: g^{y}/31) > _gag_ ‘berry’ (if the source for DX. Leer also reconstructs *_g_^{y}_ɨ:g_^{y}_e:_, and Krauss 1961 had noted that ‘the [a] of ‘berries’ corresponds inexplicably to [i] and [i:] in other Alaskan dialects.’) *_ə_ > /e/ in *_-yə̉š_^{r}_-g_^{y} ‘whistle’ (Krauss and Leer 1981) > _yesr_, *_tsəm’ (~*səm’_, *_š_^{y}_əm’_) ‘star’ (Leer 2006-2010: s/43) > _tthen’_.

(52) PA *ə > DX /ə/ in prefixes

*ŋ^{y}ə- 2s possessor (Krauss and Leer 1981)	*ngi-*
**tš^{r}'ə=* pejorative with negative verb stem (Leer 2006-2010: tš'$^{(r)}$/1)	*tr'i# ~ tr'i-*

(53) PA *ə > DX /ə/ in stems

**P-ə̓ɬ* 'together with P' (Leer 2006-2010: 0/h 8)	*-yiɬ*
**P-ɢəže* 'fork, vee, gap' (Leer 2006-2010: G/64)	*ggizr*
**tš^{r}'ə̓tɬ'(e:)* 'underbrush' (Leer 1987)	*tr'ɨtl* 'willow'
**yəx̣s* 'snow' (Leer 2006-2010: y/31)	*yith*
**x^{y}ə̓t'* 'scar' (Leer 2006-2010: x^{y}/y)	*sɨt*
**O-ɬ-tš^{r}əs-g^{y}, O-ɬ-tš^{r}a:s* 'whip O, shake O (blanket-like)' (Leer 2006-2010: *tš$^{(r)}$/61*)	*O-ɬ-trɨth* (semelfactive; *-troth* durative)

*ə compensatorily lengthens to /a/ in certain environments in the verb prefixes (Hargus 2003), as well as in stems such as **t'əɣ̇əs* 'cottonwood' (Leer 2006-2010: t'/30) > /t'aʁθ/ (*t'aghth*).

*α has a more complex set of reflexes in Deg Xinag than *ə. Krauss and Golla 1981:72 show *α > DX /ə/, but before a uvular generally *α > /ʊ/, just like Holikachuk as listed in Table 3 of their article:[28]

(54) PA *α > DX /ʊ/

**-q'αx̣* '(animal) fat' (Leer 2006-2010: q'/81)	*-q'ux*
**P-tαx̣* 'among, amidst P; during P; places where, times when' (Leer 2006-2010: t/37)	*tux*
**O-ɬ-tɬαɣ̇* 'rub, anoint O with ointment, (AB also oil)' (Leer 2006-2010: tl/3)	*O-n-ɬ-tlux* 'grease, paint O'
**ɬ-D-tɬαx̣d* 'anim. jumps, hops, moves jerkily' (Leer 2006-2010: tɬ/1)	*l-tlux*
**nə-t'αɢ* 'one (bird) flies' (Leer 2006-2010: t'/19)	*n-D-'uq*

(Again, there is compensatory lengthening to /o/ rather than /ʊ/ in certain environments within stems; e.g. **P-nαɣ̇αɬ* 'before P's eyes, in the presence of P' (Leer 2006-2010: x̣/72) > -/noʁɬ/ (*-noghɬ*).) After a uvular, sometimes *α > /ʊ/ (55), sometimes *α > /ə/ (56), and sometimes *α > /o/ (57).

(55) PA *α > DX /ʊ/ after uvular

**P-ɣ̇αn* 'by, near, at, to; from; about concerning P' (Leer 2006-2010: x̣/11), **P-ɣ̇αn* 'in the vicinity of P, by, to from P; in relation to P, about, concerning P' (Leer 2006-2010: x̣/37)	*-ghʉnh* 'from, before, in front of'
**x̣αd-ɬ* 'sled' (Leer 2006-2010: x̣/70)	*xʉtl*

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[28] **ɢαx̣* 'rabbit' (Leer 2006-2010: G/49) may have been borrowed into Deg Xinag as *ggux* via Holikachuk. This form was not used in Shageluk. Shageluk (and also Anvik) speakers use *noghniy* for 'rabbit'.

**x̣αy* ‘spruce root(s)’ (Leer 2006-2010: x̣/119)	*xuyh* ‘long root’ (spruce, willow)
**D-qαy* ‘long pointed object (e.g. spear, arrow, pole, boat, knife, needle, pin) jabs, pierces, rams’ (Leer 2006-2010: q/91)	*D-quyh* ‘scamper, poke’

(56) PA *α > DX /ə/ after uvular

*-ɢαŋ^y ‘dry out, become dry, dried’ (Leer 2006-2010: G/5)	*-gginghh*
**-nəla:-ɢαŋ^ye’* ‘nail’ (Leer 2006-2010: G/2)	*-logging*
**-qαŋ’^y* ‘husband’ (Krauss and Leer 1981)	*-qing’*
**x̣α̇ɬ(-ɬ)* ‘club’ (Leer 2006-2010: x̣/82)	*xiɬ* (Kari 1978)
**x̣αy* ‘winter’ (Leer 2006-2010: x̣/121)	*xiyh*[29]

(57) PA *α > DX /o/ after uvular[30]

**-q’αy’, -q’αye’* ‘pelvis, hip, crotch, fork of legs’ (Leer 2006-2010: q’/73)	*-q’oy*
**ɬ-q’α̇ts’* ‘cold (air, wind, weather) extends, moves, blows’ (Leer 2006-2010: q’/48)	*ɬ-q’otth* ‘be cold’ (weather)

Otherwise (when not originally adjacent to a uvular), *α > /ə/:

(58) PA *α > DX /ə/

**ʔαn’* ‘off, away, over, beyond’ (Leer 2006-2010: ’/8)	*in*
**-qe:-tα̇tɬ’* heel (Leer 2006-2010: t/22, q/129)	*-titl*
**hαn(’ə)* ‘river’ (Leer 2006-2010: 0/h 6)	*xin*

Turning now to *ʊ, Krauss and Golla 1981:72 list /ə/ as the reflex of *ʊ in Deg Xinag, possibly due to their analysis of [qY] as [q^wə] (1.2). In fact, *ʊ is generally maintained as /ʊ/ in Deg Xinag when adjacent to a uvular:[31]

(59) PA *ʊ > DX /ʊ/

**O-nə-ɬ-dʊ̇q’* ‘cram, stuff O; move bulky, unwieldy O’ (Leer 2006-2010: d/60)	*O-n-ɬ-duq* ‘make O into snowball’
**[D]-dlʊ̇q’* ‘laugh, smile’ (Leer 2006-2010: ɬ/111)	*ni#g-dluq*
**tɬ’ʊx̣, tɬ’ʊẏ* ‘grass’ (Leer 2006-2010: tɬ’/54)	*tl’ux* ‘lake grass, sedge, wide grass’
**k^yʊx̣, *k^yʊẏ* ‘big’ (Leer 2006-2010: k^y/20)	*chux*

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[29]The compound-initial/incorporated form of this stem is *xey-* (e.g. *xeyts’in’* ‘autumn’, lit. “towards winter”).

[30]Also note two cases of *α > /o/ before uvular: *O-’αx̣d* ‘move O abruptly, throw O (blanket)’ (Leer 2006-2010: ’/10) > *-’ʊx* and **nə=/na:=O-ɬ-’α̇ɬx̣ ~ ’α̇x̣ɬ* ‘butcher O (slain animal)’ (Leer 2006-2010: ’/9) > *nə#O-ɬ-’ox*. /ʊ/ is expected here; cf. (54).

[31] *ʊ > ʊ~o is attested with *-ɢʊ’k^y’/*ɢʊ’tš^r’* ‘move with forceful impetus, tumble, rush, spill’ (Leer 1987) > *l-ggok/ggʊk* ‘sg./du. run’, where the perfective stem varies between *-ggok* and *-ggʊk* (different speakers prefer one or the other). The progressive and momentaneous future stems, however, are always *-ggʊk*.

**O-zʊɣ̇* 'scrape O' (Leer 2006-2010: s/71)	*-dhux*
**qʊn'* 'fire' (Leer 2006-2010: q/177)	*qun'*
**(də)-qʊs[X]* 'cough, cold' (Leer 2006-2010: q/187)	*d-l-quth*
**q'ʊs* 'cloud' (Leer 2006-2010: q'/157)	*q'uth*
**-q'ʊs* 'neck' (Leer 2006-2010: q'/158)	*-q'uth*
**x̣ʊš* 'thorn' (Leer 2006-2010: x̣/243)	*xusr*
**qʊ-nə-ɣ̇ʊš, *qʊ-ɣ̇ʊš* 'foam' (Leer 2006-2010: x̣/245)	*xughusr, gughusr* 'foam, bubble'
**-ɣ̇ʊz* 'thigh' (Leer 2006-2010: x̣/241)	*-ghuth* 'thigh, hindquarter'
*$k^{'y}$*ə-ɣ̇ʊdz* 'ribs of a canoe, sled' (Leer 2006-2010: x̣/250)	*gughudz*
*$k^{'y}$*ə-t'ʊɣ̇* 'paddle a canoe' (Leer 2006-2010: t'/67)	*g-ɬ-t'uq* 'row'

In stems with final voiced uvular fricative, **ʊ* > /o/ (also a synchronic rule of Deg Xinag):

(60) PA **ʊ* > DX /o/ before ʁ

**ɬ-D-tsʊɣ̇* 'be tan, yellow, etc.' (Leer 2006-2010: ts/75)	*l-tthogh* 'be yellow'

Similarly, PA disyllabic stems with medial **əʁʊ* > Deg Xinag /oʁ/:

(61) PA **ʊ* > DX /o/ from compensatory lengthening

**džəɣ̇ʊ̇tɬ', *džəɣ̇ʊ̇ɬ* 'ball' (Leer 2006-2010: dž$^{(r)}$/37)	*dzoghdl*
*tš^{r}*əɣ̇ʊs* 'merganser' (Leer 2006-2010: tš$^{(r)}$/72a)	*troghth*

The change **ʊ* > /e/ seen in (62) is thus irregular. Perhaps **ʊ* irregularly lengthened to /u:/ in this word (in which case the DX reflex /e/ is as expected).

(62) PA **ʊ* > DX /e/

**ʔʊ̇q'əd, *ʔʊ̇q'* 'eddy, whirlpool, swirling water' (Leer 2006-2010: '/27) > /ʔeq'ət/

In the verb prefixes, **ʊ* is reconstructed in the areal prefix **qʊ-* (Leer 2006-2010; Thompson 1993) and optative prefix **ɣ̇ʊ-* (Leer 2000). The optative prefix is hardly used by current Deg Xinag speakers, although the available evidence suggests that its shape is/was /*ʁʊ*/- (Hargus 2004). The areal prefix, in its CV form, is /χə-/, unless preceded by the homophonous third person plural subject prefix, in which case the vowel separating the two uvular fricatives is round. Compare the forms in (63):

(63) Deg Xinag areal prefix (- 3pS prefix)

x̲inayh	'he's talking'
xux̲inayh	'they're talking'

The original rounding is thus preserved in some form for each of these two verb prefixes.

When not adjacent to a uvular consonant, generally PA **ʊ* > DX /ə/:[32]

(64) PA **ʊ* > DX /ə/ adjacent to non-uvular

**-k*^{y}*ʊ̉ts’* ‘thumb, claw’ (Krauss 2005)	*-lochitth* ‘thumb’
**O-lʊ̉k*^{y}*’* ‘handle O with a rope, string, loop…, handle O (rope, string, loop)’ (Leer 2006-2010: ɬ/105)	*P-ɨ#lıyh* ‘snare P’
**šʊχ* ‘moisture, frost’ (Leer 2006-2010: š/99), **ɬ-D-žʊɣ̇* ‘it is moist, damp, covered with frost’ (Leer 2006-2010: š/100)	*srix* ‘frost’, *ni#l-zrix* ‘frost, be frosty’

Occasionally, **ʊ* > /ə/ takes place even when a uvular is adjacent to the round vowel.

(65) PA **ʊ* > DX /ə/ adjacent to uvular

**O-tə-(nə-)ɬ-ɣ̇ʊ̉t’* ‘bend, curve O’ (Leer 2006-2010: x̣/228)	*O-t-ɬ-ghit*
**qʊy* ‘vomit’ (Leer 2006-2010: q/191)	*qıyh*

The similar developments of Proto-Athabaskan **α* and **ʊ* in Deg Xinag (consistent preservation of rounding before a uvular, inconsistent loss of rounding after a uvular, regular loss of rounding adjacent to a non-uvular) suggest that **α* and **ʊ* may have first merged as **ʊ*, and then **ʊ* merged with **ə* unless adjacent to a uvular. If this is correct, then **α* may have been a round vowel, which would have facilitated the merger with **ʊ*. Note that in closely related Koyukon, the reflex of **α* is described as a ‘low back rounded reduced vowel similar to *ou* in English *tough*. It is used only in the Central and Lower dialects…’ (Marlow 2000:lxxi), the reflex of **α* apparently merging with the reflex of **ʊ* in the Upper dialect. Other languages from Krauss and Golla 1981 where **α* and **ʊ* have merged are all in Alaska: Holikachuk, Lower Tanana, and Kolchan (a.k.a. Upper Kuskokwim). Further, if **α* is a shorter, more centralized version of **a:* (*ɑ:/ɔ:), this supports the view of the PA vowel **a:* as having been round, *[ɒ:] or *[ɔ:].

The number of lexical items with **ʊ* in Deg Xinag has remained fairly stable over time compared to Proto-Athabaskan. One can then reasonably wonder what the historical sources are for the six Deg Xinag lexical items with /ʊ/ adjacent to a non-uvular given above in (6). Four of these appear to have been borrowed from neighboring languages. One, /pʊsəj/ ‘cat’, was probably borrowed from Yup’ik *puss’iq*. (Note that some speakers use /vosə/ for ‘cat’.) Three of these might be borrowings from Holikachuk, which did not undergo the **k*^{y} > /k/, /ʧ/ split found in DX.[33] There was and still is lots of contact between Deg Xinag and Holikachuk speakers and their descendants. Similar forms are attested not only in Holikachuk but also in Koyukon:[34]

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[32]The development of **ʊ* > /o/ in **O-ɬ -t’ʊg*^{y} ‘insect stings O…’ (Leer 2006-2010: t’/67) as *vichit’ogɨditthiy* ‘bug with stinger’ (Kari 1978) is therefore unexpected.

[33]/ʧ/ is found in one Holikachuk word, *chux* ‘big’ (Giulia Oliverio, p.c.). This is probably a borrowing from DX.

[34]Data from Holikachuk (Kari et al. 1978) and Koyukon (Jetté and Jones 2000) is cited in the practical orthographies of those languages.

(66) DX velar + [ʊ] shared with Holikachuk and Koyukon

Deg Xinag	*Holikachuk*	*Koyukon*
kula 'poor thing'	*kula* 'poor one'	*kulaa* 'how pathetic! how pitiful!'
dikul 'gratitude'(?)	*dikwil* 'friendship'	*dekul, -dekule* 'poor, pitiful person'
yuk (listener's expression at end of story)	*yuk* 'end (of story)'	*yuk* 'right! you guessed it (riddle)'

However, for two remaining Deg Xinag lexical items with velar + [ʊ], no neighboring language source is known:

(67) DX velar + [ʊ] not shared with any known neighboring languages

tthik'u-	'uphill, into woods'
x-k'u#O-ł-'anh	'medically assist O'

4 Conclusion

This article has provided instrumental confirmation that the vowel inventory of Deg Xinag contains three long/full vowels and two short/reduced vowels, none of which are the typologically expected /i u/. The Deg Xinag vowel phonemes have more centralized allophones before retroflex consonants and lowered allophones before uvulars. Centralization before retroflex consonants is reminiscent of the way in which certain Upper Tanana vowels developed, as suggested by Tuttle and Lovick 2008. Lowering before uvular consonants has taken place in other Athabaskan languages, such as Witsuwit'en.

Although Krauss 1962, on the basis of the data available to him, suggested that the Deg Xinag sequence uvular + [ʊ] (and mirror image) might be analyzable as labio-uvular + /ə/, additional study of the language has revealed a wider distribution of Deg Xinag /ʊ/. A small number of lexical items, most likely borrowings, contain /ʊ/ next to non-uvulars. These indicate that the synchronic labio-uvular analysis is not tenable.

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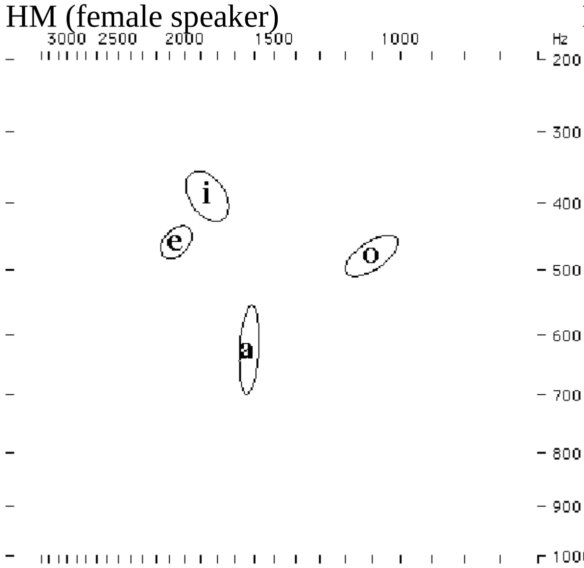
6 Appendix: vowel plots

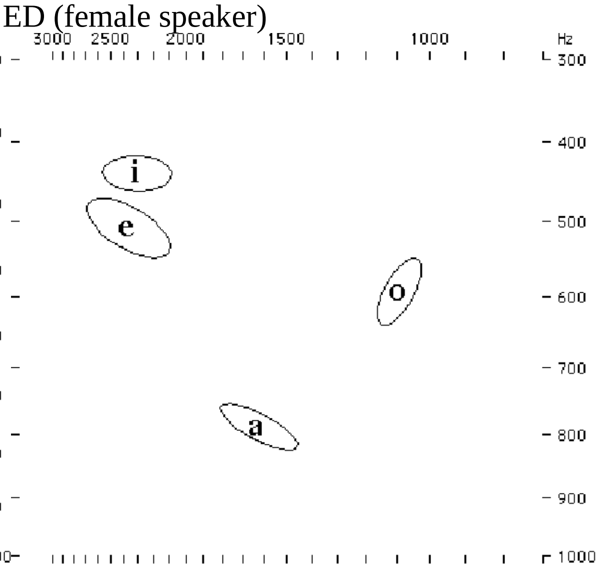
In this appendix, vowel plots for all eight speakers are presented, including HM, seen above in the text. Vowel plots in this section use the following symbols: <i> = [ə], <u> = [ʊ] (which are used to spell these vowels in the practical orthography designed by Krauss 1962). Other symbols have their normal phonetic values. It can be seen that some speakers have more variability in their production of vowels than other speakers.

6.1 Alveolar__alveolar

HM (female speaker)

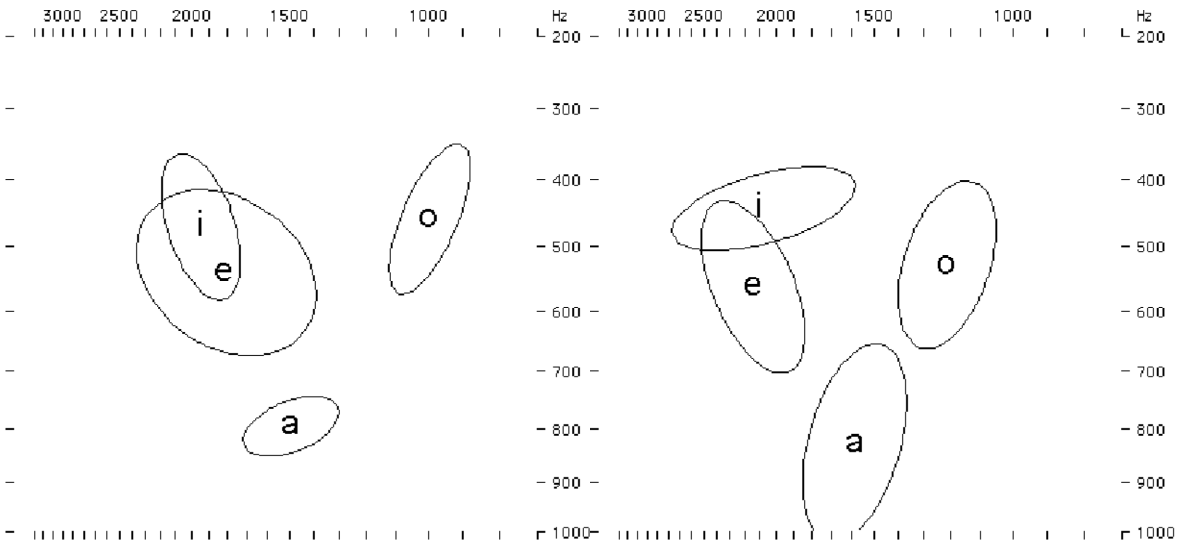


ED (female speaker)



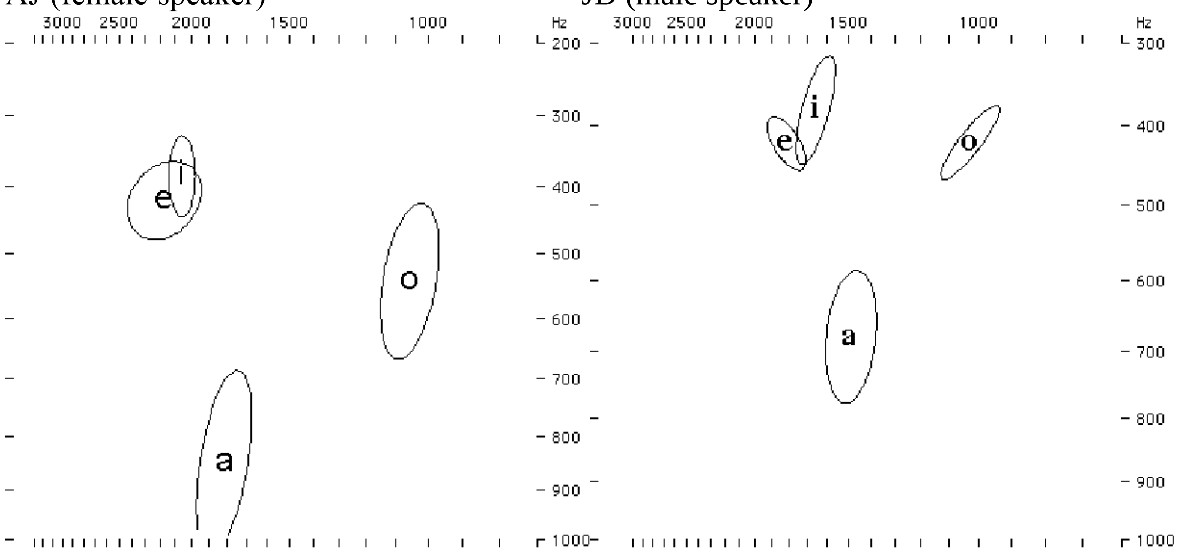
KH (female speaker)

LH (female speaker)

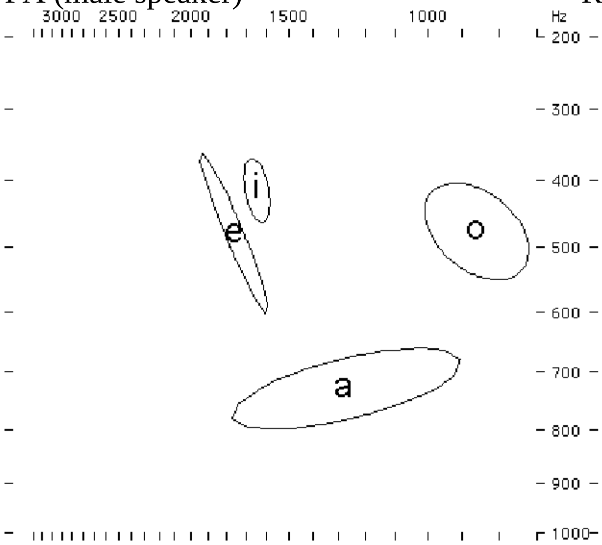


AJ (female speaker)

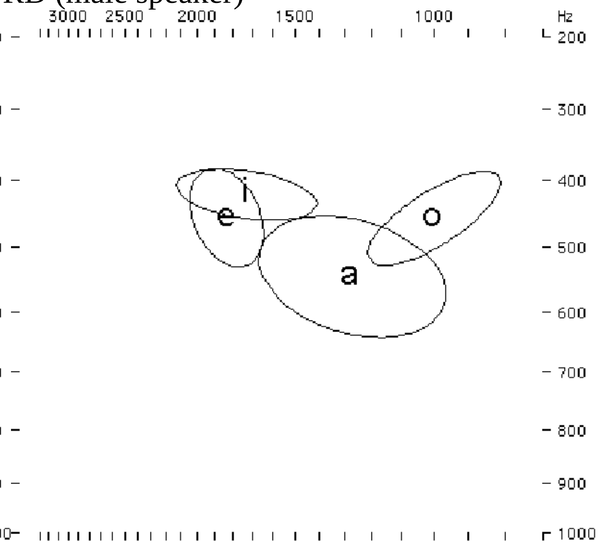
JD (male speaker)



PA (male speaker)

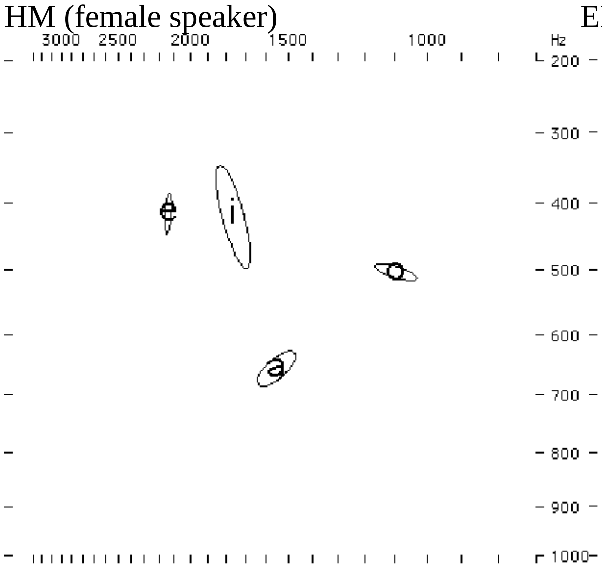


RD (male speaker)

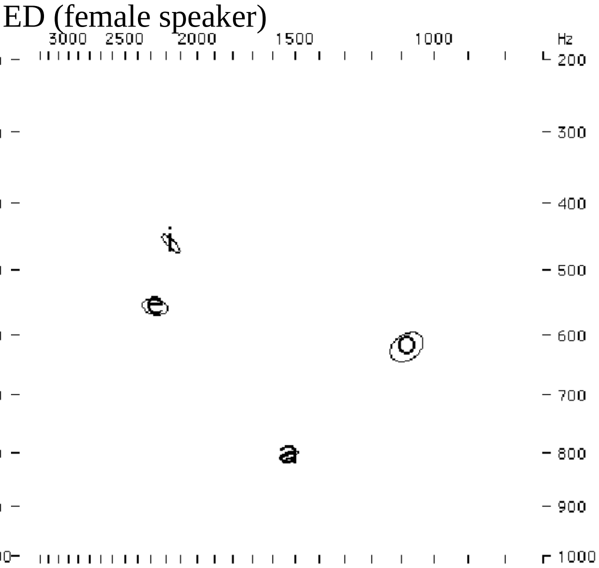


6.2 Retroflex___alveolar

HM (female speaker)

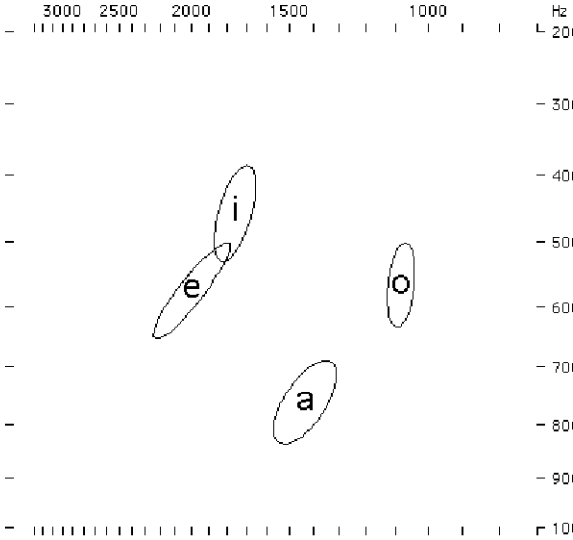


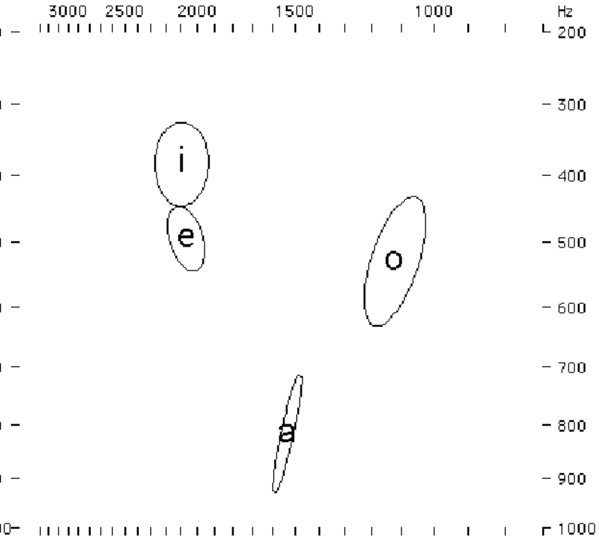
ED (female speaker)



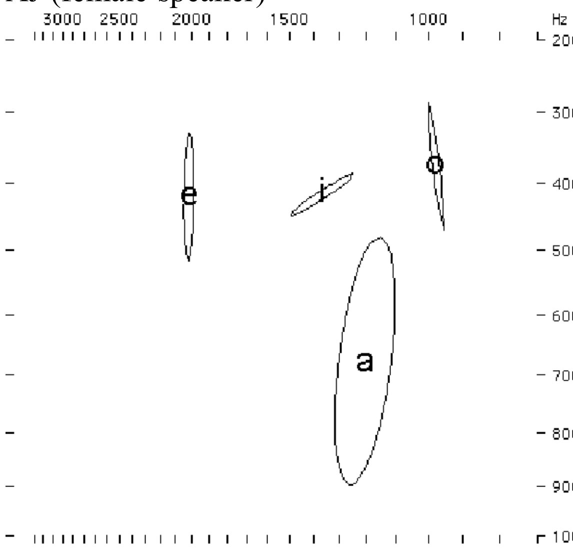
KH (female speaker)

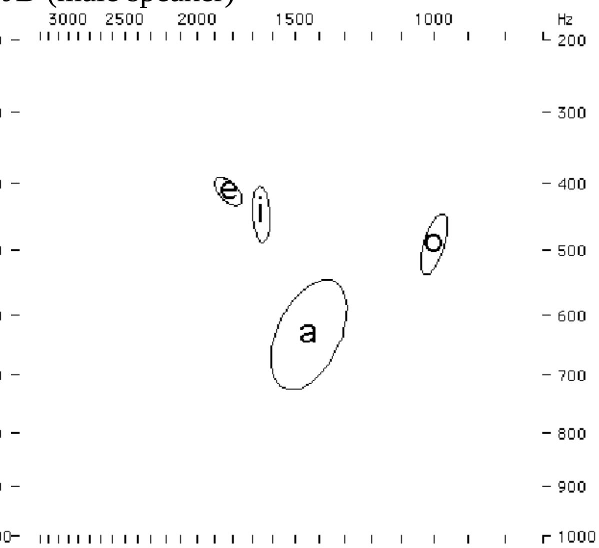
LH (female speaker)



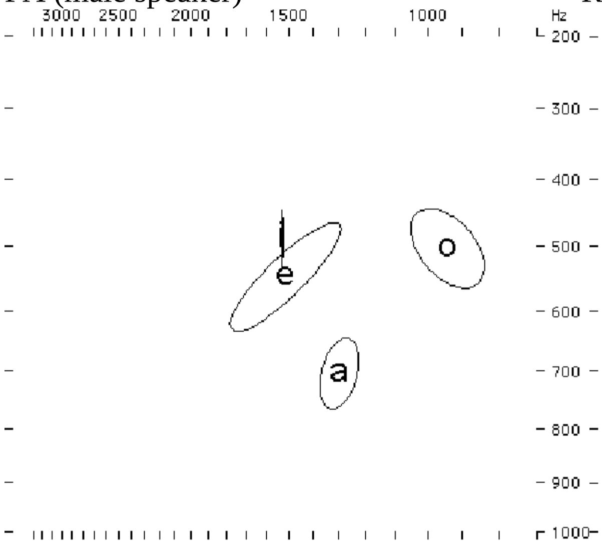


AJ (female speaker) JD (male speaker)

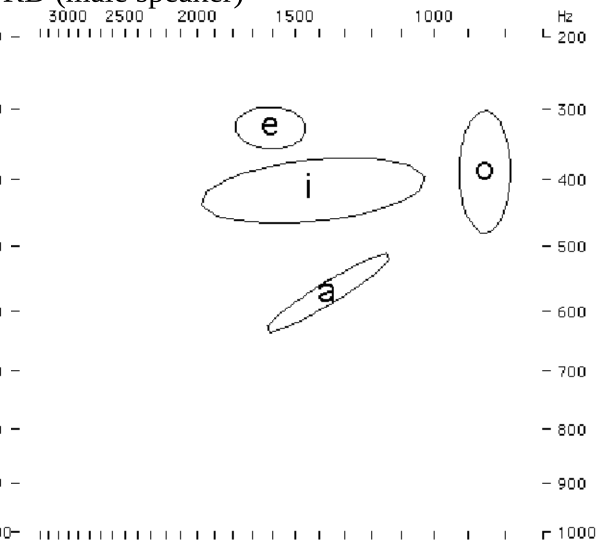




PA (male speaker)

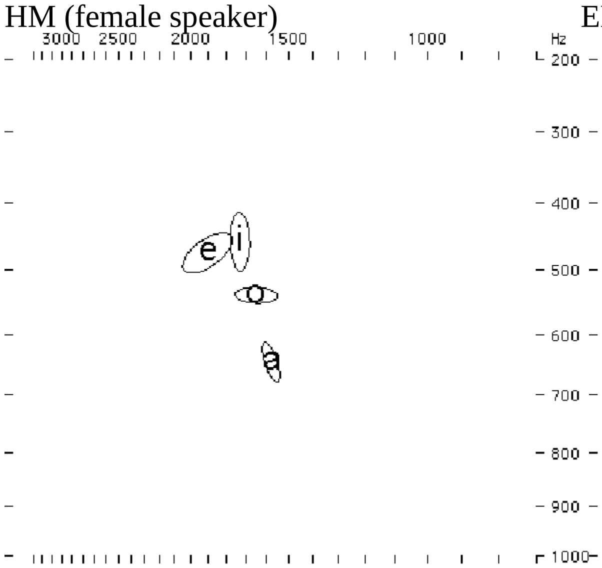


RD (male speaker)

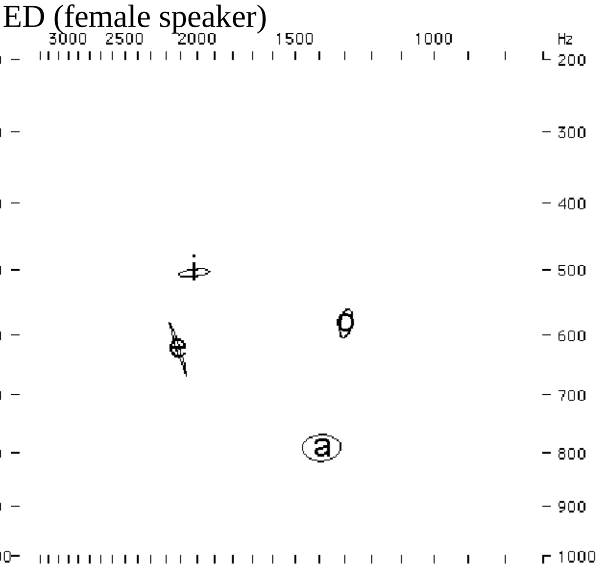


6.3 Alveolar___retroflex

HM (female speaker)

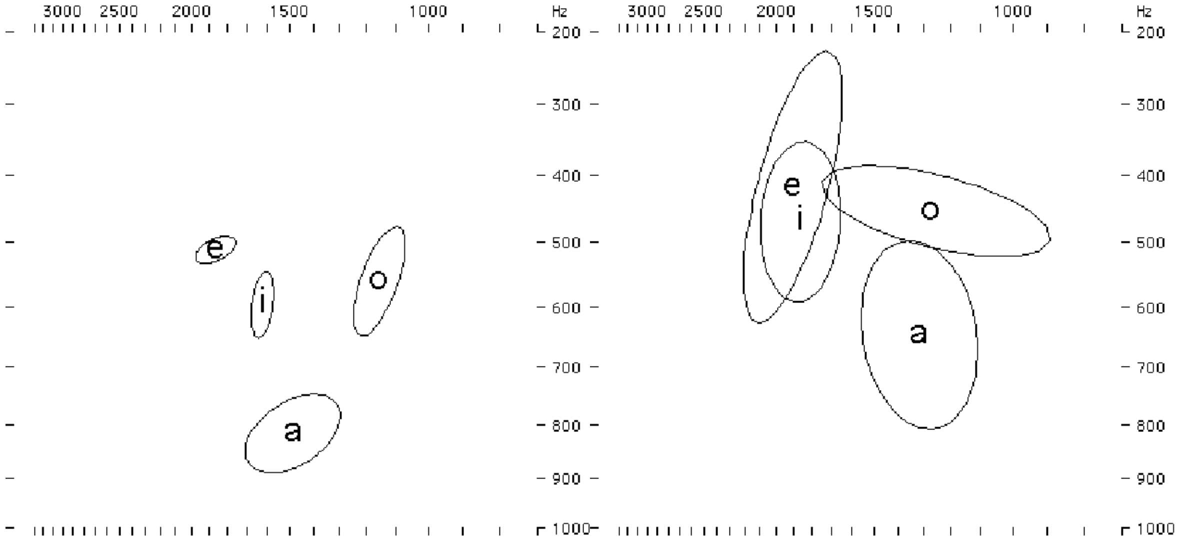


ED (female speaker)



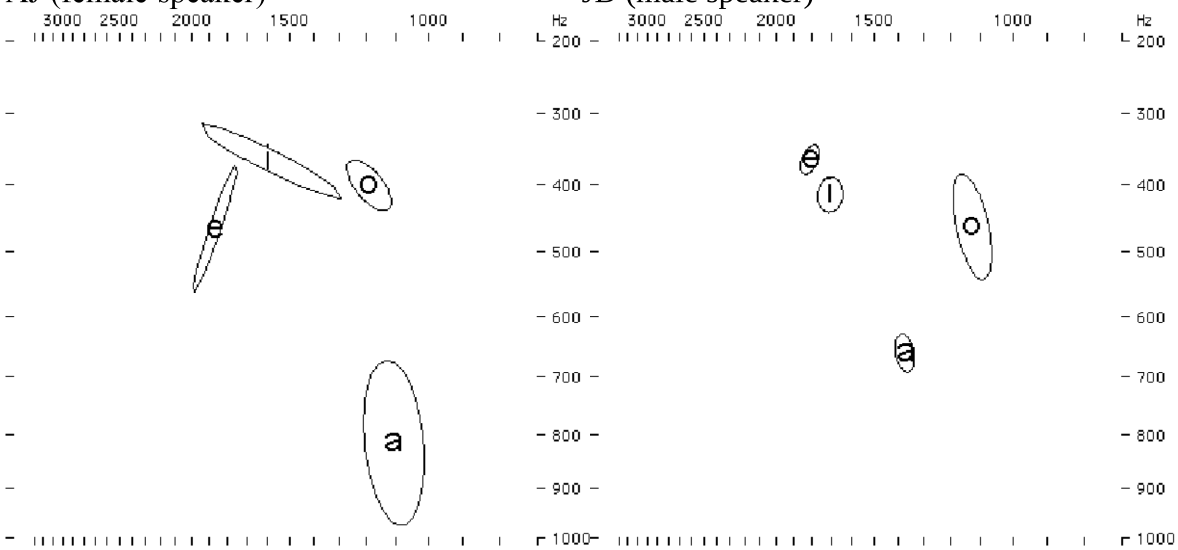
KH (female speaker)

LH (female speaker)

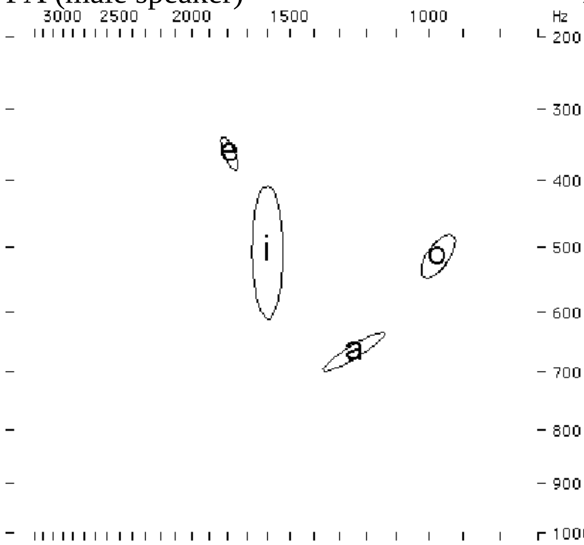


AJ (female speaker)

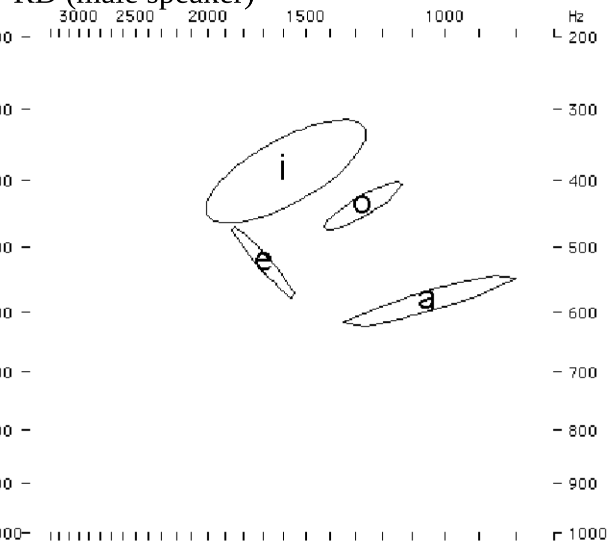
JD (male speaker)



PA (male speaker)

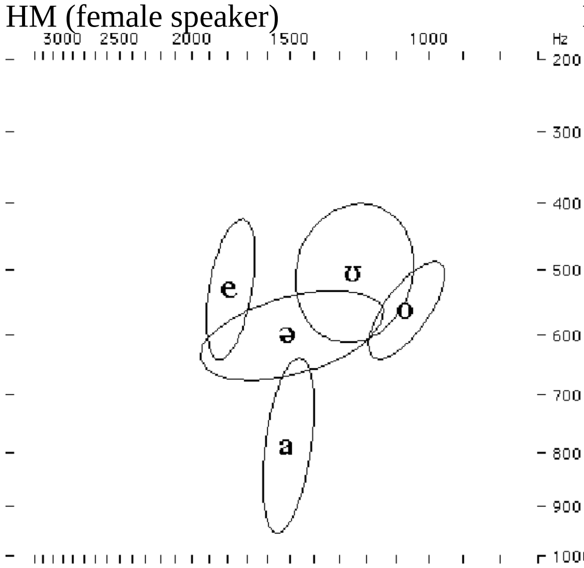


RD (male speaker)

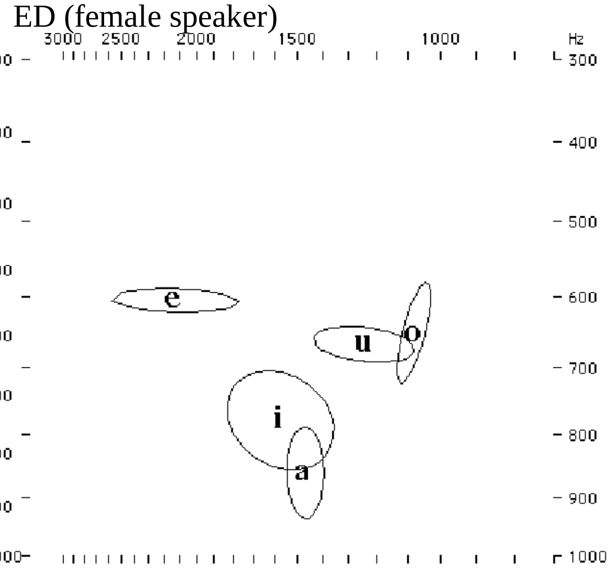


6.4 Uvular___alveolar

HM (female speaker)

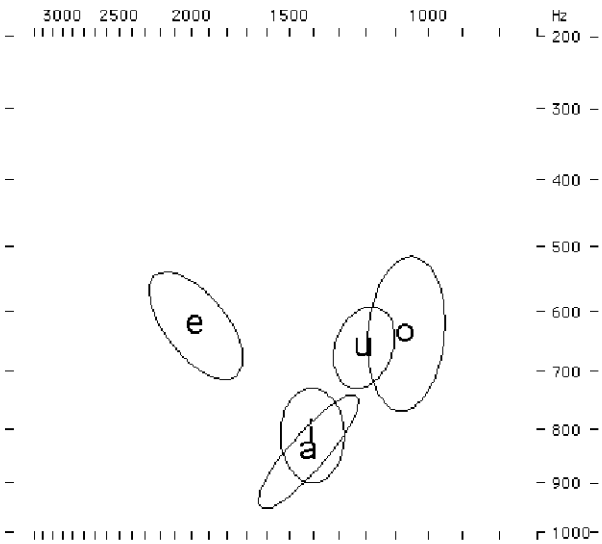


ED (female speaker)

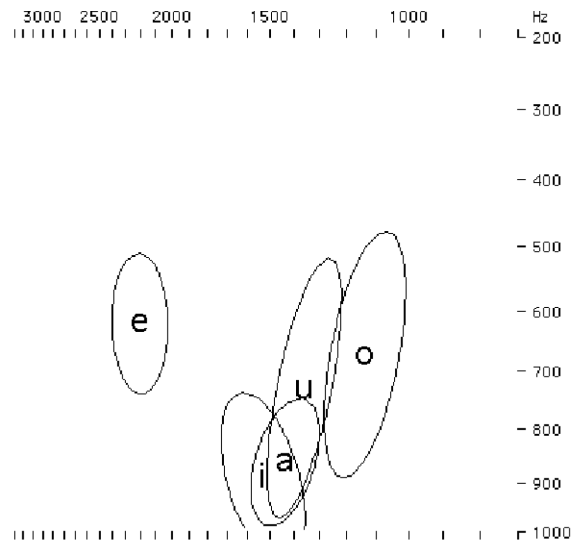


KH (female speaker)

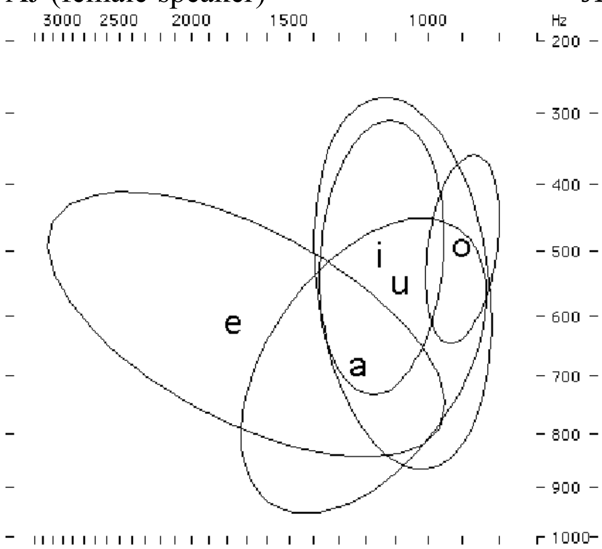
LH (female speaker)

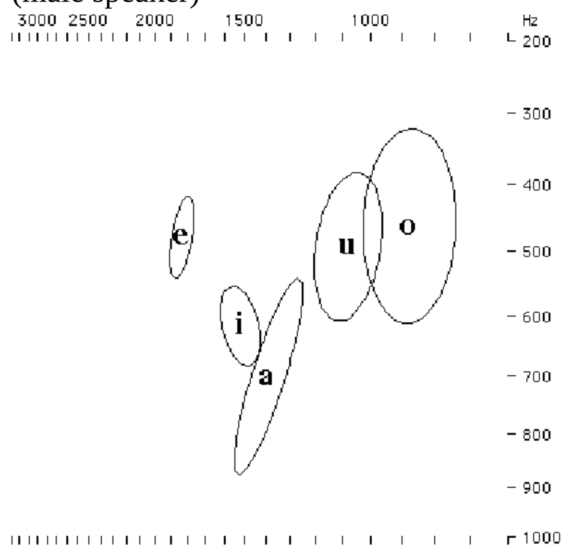


AJ (female speaker)

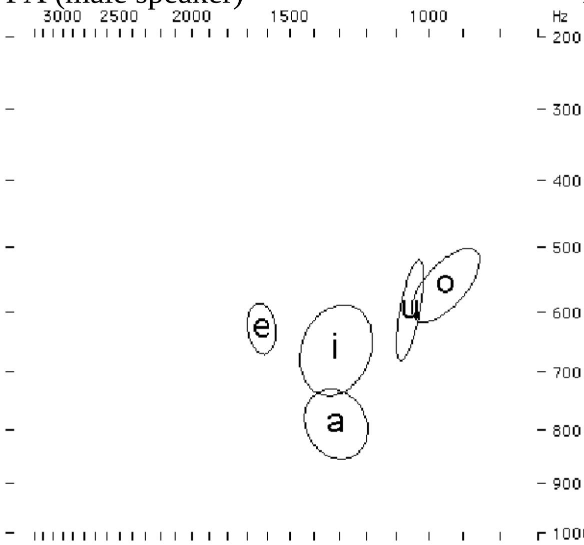


JD (male speaker)

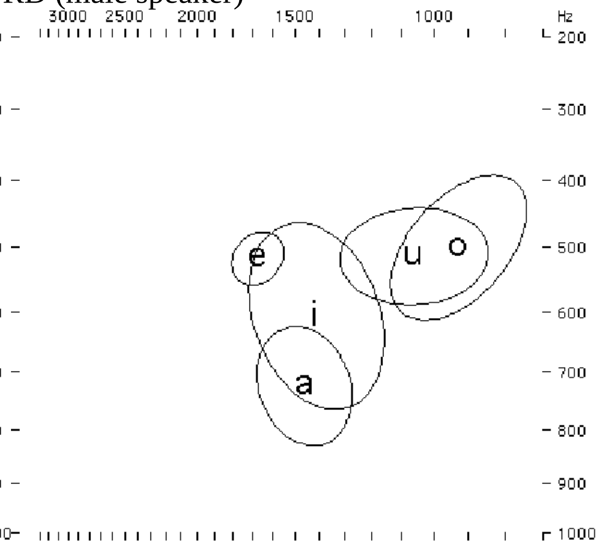




PA (male speaker)

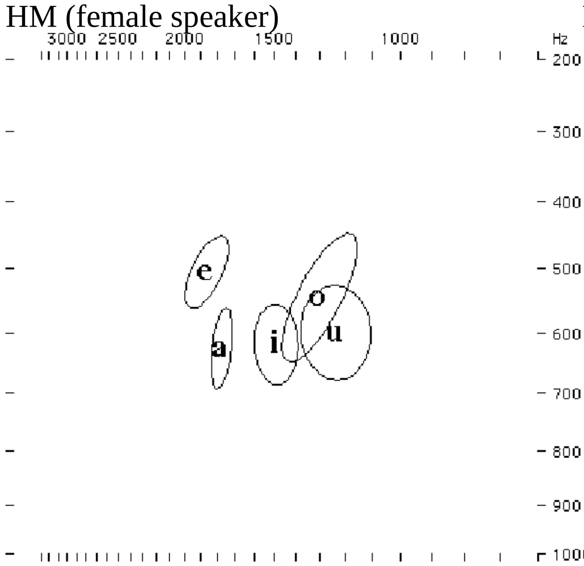


RD (male speaker)

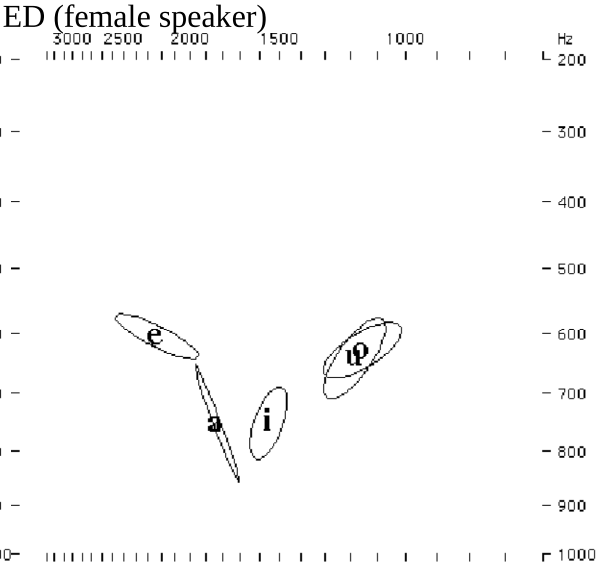


6.5 Alveolar___uvular

HM (female speaker)

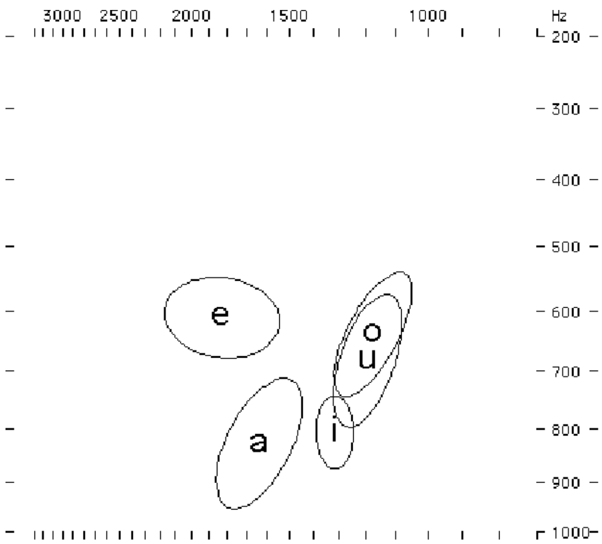


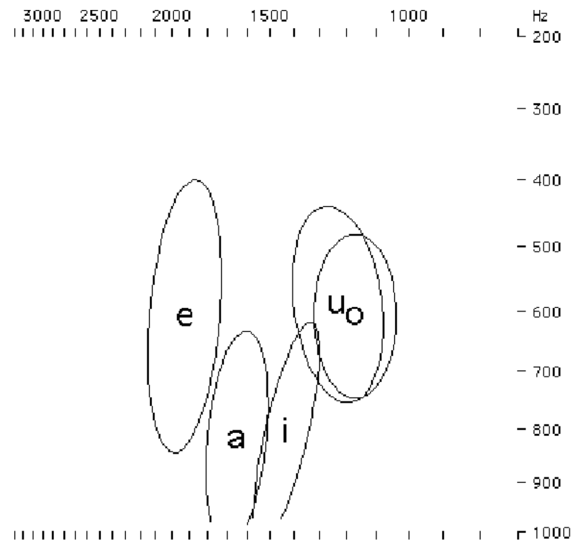
ED (female speaker)



KH (female speaker)

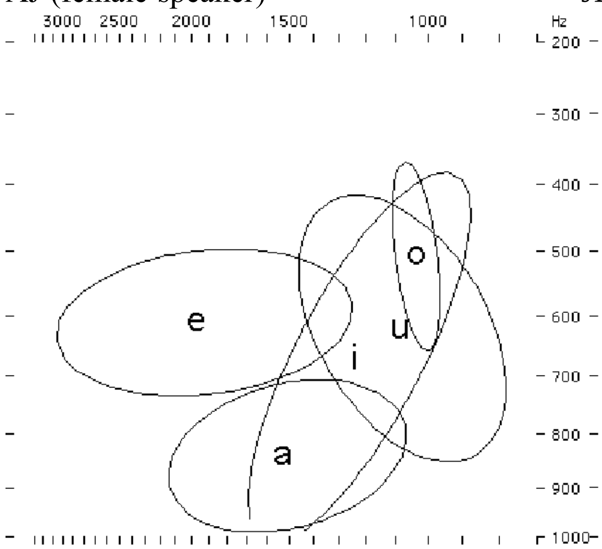
LH (female speaker)

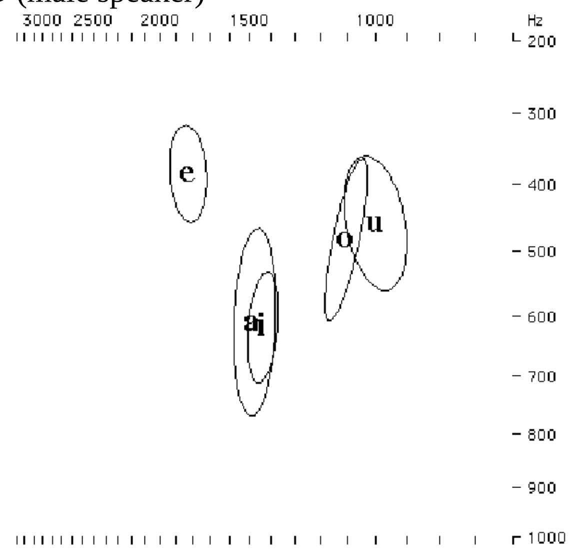




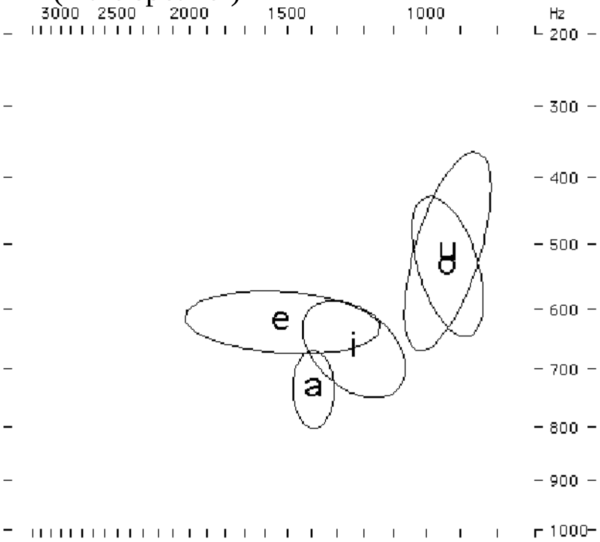
AJ (female speaker)

JD (male speaker)





PA (male speaker)



RD (male speaker)