

The interaction between language usage and acoustic correlates of the Kuy register distinction

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Abstract

Contact is often cited as an explanation for the convergence of areal features and has been proposed as an explanation for the emergence of tonal languages in Mainland Southeast Asia. The current production study probes this hypothesis by exploring the relationship between tonal language usage and the acoustic correlates of the register distinction in Kuy, a Katuic language, as spoken in a quadrilingual (Kuy, Thai, Lao, Khmer) Kuy community in Northeast Thailand. The results demonstrate greater persistence of fundamental frequency (f_0) differences over the course of the vowel alongside more tonal language experience for male speakers; however, analysis of individual differences finds that $H_1^* - H_2^*$, a correlate of voice quality, is the primary cue for male speakers with greater tonal language experience. For female speakers, a tradeoff is found between f_0 and voice quality cues alongside tonal language experience at both the group and individual levels. These findings provide evidence for a model by which contact may serve to enhance existing, non-primary cues in a phonological contrast by shifting cue distributions, thereby increasing the likelihood that these cues will come to be perceived as prominent and phonologized.

Keywords: sound change; cue weighting; language contact; bilingualism; register; tonogenesis

1 Background

Areal linguistic features that are shared across genetically unrelated languages are generally understood to result from extended language contact. The literature is rife with examples of contact effects, although in many cases, it is difficult to tease apart the role of contact in language change from a structural predisposition for the given change or from mere coincidence. Closely tied to work on language contact is the experimental literature on bilinguals' usage of L1 phonetic cues in the production and perception of contrasts in an L2 language and of the effects of L2 language exposure and usage on L1 phonological categories. The current study contributes to the intersection of this literature by exploring how variation may be structured by bilinguals' language usage and experience, setting the stage for larger-scale contact effects. The phenomenon of interest is the register contrast in a variety of Kuy (Katuic; Austroasiatic) spoken in Thailand at the borders of Cambodia and Laos. As in other register languages, the Kuy register distinction is characterized by a cluster of cues, including fundamental frequency (f_0), amplitude, voice quality (or, more narrowly, phonation), and vowel quality. Speakers, however, differ in the extents to which each cue manifests in the register distinction; the object of study is the relationship between the distribution of cues and language experience and usage patterns, particularly at the individual level.

Kuy populations in Thailand live in a historically quadrilingual society, but the continual increasing centralization of Thailand has pushed language usage to trend largely towards Kuy-Thai bilingualism. As standardization pressures lead Kuy speakers to increasingly shift to the national language, Thai, we expect changes involving cues that are shared between these languages, such as f_0 , which is the primary cue for the tonal contrast in Thai but only one of several acoustic cues for the register contrast in Kuy. This study delves into individual differences in the interaction between language usage and other social factors and the acoustic correlates of the Kuy register distinction. The goal of this study is to provide a close analysis of how we might understand the macro-effects of language contact on linguistic structure in language used by a community through the micro-effects of bilingualism on the realization of a phonological contrast at the individual level. The results reported in this study show a clear shift in cue prominence in the register contrast that correlates with language experience. I argue that these results show how the

rearrangement of cue weights at the individual level can be shaped by patterns of bi- and multilingualism and accumulate to bring about societal-level sound changes that may be understood as language contact effects.

1.1 Cues, Contrast, and Contact

Tone is one of the most well-known areal features of Mainland Southeast Asia (MSEA), an area that comprises five large families: Sino-Tibetan, Kra-Dai, Hmong-Mien, Austro-Asiatic, and Austronesian (Henderson, 1965; Matisoff, 2001; Enfield, 2005, 2011). In a sample of 186 MSEA languages, Kirby & Brunelle (2017) find that the Sino-Tibetan, Kra-Dai, and Hmong-Mien languages are all tonal. Of the Austroasiatic languages, about one-third have register contrasts, a number of which incorporate pitch, and another third have three or more tones (with many also using voice quality concurrently). The Austronesian languages for the most part utilize neither tone nor register, with the exception of a number of languages (almost all Chamic) that utilize pitch in register contrasts. One Chamic language, Tsat, is not strictly in MSEA, but has a 5-tone system (Thurgood, 1999, p. 274). *Tonogenesis*, the emergence of tone, has occurred in a number of languages. Of relevance to the language families of Southeast Asia is tonogenesis in Chinese sometime between the first millennium BCE and CE (Sagart, 1999, p. 101), and in Kra-Dai, Hmong-Mien, and Viet-Muong around the same time, elucidated through historical and comparative evidence (Maspero, 1911, 1912; Haudricourt, 1954b,a; Li, 1966; Mei, 1970; Chang, 1972; Pulleyblank, 1978; Gedney, 1989; Ferlus, 1998; Ostapirat, 2005; Ratliff, 2010). While some sources attribute tonogenesis, either implicitly or explicitly, in these languages to contact with Chinese due to identical-looking tone systems (Benedict, 1996; Matisoff, 1973, p. 88; Pulleyblank, 1986; Sagart, 1999; Ferlus, 2004, p. 307), there is doubt about the source necessarily being Chinese, the tone systems directly being “borrowed”, and about contact as an explanation in general (Ratliff, 2015; Brunelle & Kirby, 2015). Ratliff (2015, p. 261), however leaves room for the possibility of contact making languages more ‘tone prone’. The existence of tonal languages in generally non-tonal language families but that are in areas with other tonal languages (Berezinak, 1995, p. 93; Premsrirat, 2001, p. 122; Schuh, 2003; Clements & Rialland, 2008, p. 72, 74; Hopkins, 2012, p. 423) offers circumstantial evidence for this idea, although there are several languages not in close contact with tonal languages that develop tone as well (Bhatia, 1975; Purcell et al., 1978; Rivierre, 1993; Leer, 1999; Kim, 2000; Rivierre, 2001; Kim, 2004; Kingston, 2005; Wayland & Guion, 2005; Silva, 2006; Kirby, 2014; Kanwal & Ritchart, 2015).

The contrast of interest in the current study is that of *register*. Register is a phonological contrast that employs a constellation of suprasegmental features, including pitch, voice quality, and vowel quality (Henderson, 1952, p. 151; Gregerson, 1976; Huffman, 1976; Ferlus, 1979; Edmondson & Esling, 2006). Many languages that have a two-way register distinction may be described as having a modal-breathy, creaky-modal, tense-lax, or stiff-slack distinction, for example, many of which are terms referring to voice quality—the phonetics associated with each of these terms differs in nuanced ways (Halle & Stevens, 1971; Ladefoged, 1973; Laver, 1980; Maddieson & Ladefoged, 1985; Gordon & Ladefoged, 2001; Gobl & Ní Chasaide, 2013). These pairs are often collectively referred to as “high” and “low” register. Table 1, adapted from Brunelle et al. (2020) and added to, summarizes crosslinguistic cues for register from various studies (e.g. Bickley, 1982; L. Thongkum, 1988; Andruski & Ratliff, 2000; Blankenship, 2002; Miller, 2007; DiCanio, 2009; Keating et al., 2011; Kuang, 2011a,b; Esposito, 2012; Esposito & Khan, 2012; Pan et al., 2011; Garellek, 2012).

Tonogenesis is a subtype of a more general process termed *transphonologization* (Haudricourt, 1965; Hyman, 2013), in which “secondary cues” in a phonological contrast come to replace the

Table 1: Crosslinguistic correlates of register contrasts

Cue	High Register	Low Register
Open quotient	Lower	Higher
Spectral tilt	Lower	Higher
Harmonics-to-noise ratio	Higher	Lower
Intensity	Higher	Lower
f0	Higher	Lower
F1	Higher	Lower
F2 ¹	More peripheral?	More centralized?
VOT	Shorter	Longer
Vowel duration	Shorter	Longer

“primary cues”. Transphonologization may begin with enhancement of a secondary cue in a segmental contrast (in the case of tonogenesis, this would be f0), leading to redundant cueing of the contrast alongside the original cue (voicing or voice quality, for example). Following this redundancy, the original cue may be weakened, eventually leading the originally secondary cue to become primary (Maran, 1973; Hyman, 1976). Alternatively, it is possible that the primary cue first weakens, leading to the potential for merger. In this situation, enhancement of another cue may be a strategy to avoid merger, which may be particularly important if the contrast has a high functional load (Baese-Berk & Goldrick, 2009; Wedel et al., 2013). The following section lays out the linguistic and sociolinguistic details of Kuy to provide the context for understanding how multilingualism can play a role in transphonologization.

1.2 The linguistic landscape of Tambon Tum

The Kuy in Thailand primarily live in the three provinces of Buriram, Sisaket, and Surin, all of which border Cambodia. As a region at the crossroads of three modern countries (Thailand, Laos, and Cambodia) and their predecessors, multilingualism has been the norm for centuries. Following a brief presentation of the phonology of Kuy and the contact languages of the area, I will provide relevant information about the sociolinguistic background of Kuy as background for understanding the intersection of language usage and sound change.

1.2.1 Phonology of Kuy and surrounding languages

The current study focuses on Kuy as spoken in Tambon Tum of Amphoe Prang Ku in the Sisaket province of Northeastern Thailand. Discussion of phonology in this section will be limited to facts relevant to the current study, but the reader may refer to Sriwises (1978), Yantreesingh (1980), Suwannaraj (1990), Sangmeen (1992), Sukgasame (2003), Phimjun (2004), and Gehrmann (2016) for fuller descriptions on different Kuy, Kuay, and Nyeu varieties. The consonants and vowels of Kuy as laid out by Phimjun (2004) may be found in Tables 2 and 3.² Phimjun’s inventory is based off data elicited from Kuy as spoken in Tambon Ku, which borders Tambon Tum to the south. This inventory matches what I observed in the Kuy of Tambon Tum (with the exception of the diphthong /wa/, which I did not come across).

Kuy has a two-way register contrast between *modal* and *breathy* voice, a common feature of Austroasiatic languages (Jenny & Sidwell, 2014, p. 53). While this contrast may also be termed high register vs. low register, the current study will refer to these categories as modal and breathy

Table 2: Consonants of Kuy (adapted from Phimjun (2004, p. 24–25))

	Labial	Alveolar	Palatal	Velar	Glottal
Stop	p p ^h b	t t ^h d	c c ^h	k k ^h	?
Nasal	m	n	n̪	n̪	
Fricative		s			h
Trill		r			
Lateral		l			
Glide	w		j		

Table 3: Vowels of Kuy (adapted from Phimjun (2004, p. 27))

	Front	Central	Back
High	i i:	ɯ ɯ:	u u:
High-mid	e e:	ɤ ɤ:	o o:
Low-mid	ɛ ɛ:	ʌ ʌ:	ɔ ɔ:
Low	a a:		ɑ ɑ:
Diphthongs	ia	ɯa	ua

voice, following previous literature on Kuy. Phimjun does not discuss whether all vowels are represented in both registers; however, Gehrmann (2016) reviews multiple sources, confirming that different Kuy varieties have different restrictions. Kuy in Tambon Tum displays gaps as well, but I have not yet determined all of them. Voiceless unaspirated and aspirated stops are neutralized before breathy vowels, a common feature of Katuic (Huffman, 1976; Diffloth, 1982; Gehrmann & Kirby, 2019). Sriwises (1978, p. vii) and Sukgasame (1993, p. 249) describe modal voice as having a higher pitch overall than breathy voice. Alongside f0 differences, L. Thongkum (1989) also finds higher amplitude in modal voice but conflicting patterns for differences in the first formant (F1) and duration.

Kuy monomorphemic words are maximally of the shape C(V/N).CRVC, in which C stands for a consonant, N a syllabic nasal, and R a liquid. The first syllable is limited in three ways: (1) The onset must be simplex, (2) the nucleus must be either a minimal vowel that ranges between nothing and a schwa or a syllabic nasal homorganic with the onset of the second syllable, and (3) there is no coda. One example of a word with the maximal syllable structure is /cntrʌŋ/ ‘diligent’.

The phonological details for Thai, Lao, and Khmer will be restricted to tone and register, which are relevant to this study. Standard Thai has five tones: mid, low, high-falling, high-rising, and low-rising (Abramson, 1962; Tingsabadh & Deeprasert, 1997; Iwasaki & Ingkaphirom, 2005). Closed syllables with a stop coda may only take one of two tones: if the vowel is short, the tone may be low or high; if it is long, the tone may be low or high-falling. Depending on the variety, Southern Lao may have five or six tones—the Sisaket variety has five tones in open syllables: low-rising, high-falling, high, glottalized low, and glottalized mid-falling. Closed syllables with a stop coda may be mid-rising or high if the vowel is short and glottalized low or glottalized mid-falling if it is long (Brown, 1965; Hoonchamlong, 1984, Sipipattanakun, 2014, p. 109). Northern Khmer has neither tone nor register.

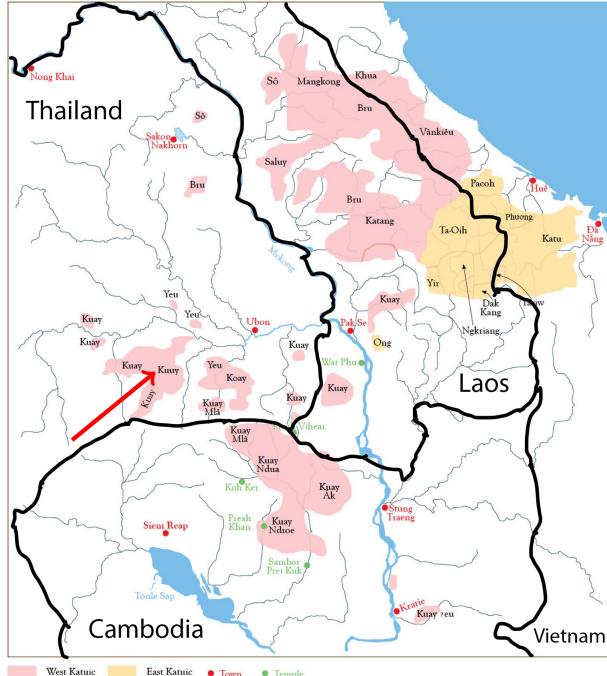


Figure 1: Distribution of Katuic (reproduced with permission from Diffloth 2011, p. 10)

1.2.2 Sociolinguistic background of Kuy

The Kuy in Thailand are historically quadrilingual in Kuy, Khmer, Lao, and Thai. These four languages exist in a usage hierarchy: in a classification devised by (Smalley, 1994), Standard Thai [ISO 693-3: tha] sits at the top, being the *national language* taught in schools. Just under Standard Thai is the *regional language*, Northeastern Thai [ISO 693-3: tts], encompassing several varieties spoken in Isan that are contiguous with varieties of Lao [ISO 639-3: lao] in Laos. Linguistically, all these varieties are grouped together as “Lao”, but given the political boundary between Thailand and Laos, there are various sociolinguistic differences between Northeastern Thai and Lao. The Kuy speak a variety of Southern Lao. Next in the hierarchy is Khmer, spoken along the Thailand-Cambodia border, a *marginal regional language* with a sizable population of speakers and which is codified as the national language just across the border. The variety spoken by the Kuy population is Northern Khmer [ISO 639-3: kxm]. At the bottom of this hierarchy is Kuy [ISO 639-3: kdt], a *marginal language* that lacks national status. Kuy is a West Katuic language in the Austroasiatic language family spoken at the border of Thailand, Laos, and Cambodia. It lies in a dialect continuum with Kuay (which shares the same ISO 639-3 code) and Nyeu (or Yeu) [ISO 639-3: nyl] varieties. These groups are also known by the exonym Suay. Figure 1 shows the distribution of the Katuic languages from Diffloth (2011, p. 10). The red arrow I have added points to the Kuy variety, spoken in Tambon Tum, in the current study. I have added country names and borders (in thick black) to supplement Diffloth’s map.

For brevity, and clarity, the four languages in this study will be generally be referred to as Kuy, Khmer, Lao, and Thai, while admitting that these terms homogenize and oversimplify linguistic and social distinctions. The Kuy have historically assimilated to neighboring Khmer and Lao groups, leading to shrinking of the Kuy-speaking region in recent times, despite growth of the population (Seidenfaden, 1952; Yantreesingh, 1980, p. 3; Smalley, 1988, p. 396). Extrapolating from the 2008 General Population Census of Cambodia, there were approximately 28,630

Kuoy speakers in Cambodia in 2008 (National Institute of Statistics, 2009). Chazée (1999) cited approximately 50,000 speakers in Laos. The 2015 census only included counts for ethnic groups who made up at least 1% of the population—extrapolating from this data, there were no more than 64,922 ethnic Kuy in Laos in 2015 (Lao Statistics Bureau, 2015). Premsrirat (2006) cited approximately 400,000 speakers in Thailand. The 2010 census counted 318,012 speakers of local/indigenous languages throughout the country (National Statistical Office, 2015), although this number is likely an underrepresentation. At the time of Premsrirat (2006), the Kuy had an affection for their language, but the use of Lao was seen as more prestigious and was generally the language of choice outside the home.

Demographic data looking at the progression of language shift may be seen in Tables 4 and 5. These data are from 117 speakers (and are a superset of the participants in the current study) interviewed in 2018 and 2019. The results are split by generation. Table 4 breaks down speakers' ability in Khmer and Lao and shows a generational shift in the degree of multilingualism: while the older generation is fully tri- or quadrilingual, there are much fewer quadrilingual speakers in the younger generation and there are even 4 individuals who are only bilingual in Kuy and Thai. Table 5 shows self-assessment of speaking ability in each language as compared to Kuy. The most notable pattern is the switch from the majority of speakers rating their Thai ability as less than their Kuy ability (31/59) to the majority of speakers rating their ability equally in the two languages (31/58). While past literature has described Kuy as losing ground to Khmer or Lao, the current numbers show that in recent times, it is primarily Thai that speakers are shifting to.

Table 4: Lao and Khmer speaking ability (based on author's survey data)

Age	Neither	Khmer only	Lao only	Both	Total
>45	0	0	4	55	59
≤45	4	2	14	38	58

Table 5: Speaking ability compared to Kuy (based on author's survey data)

Age	Thai				Khmer				Lao	
	less	same	more	less	same	more	less	same	more	
>45	31	25	3	45	9	1	44	14	1	
≤45	14	31	13	35	4	1	39	9	4	

Ban Khi Nak School, established up to fourth grade in 1939, is the school that was attended by almost all participants in this sample. Teachers in the past were primarily hired from the local area, so students could use Kuy to varying extents in school with the expectation that teachers would at least understand. However, this expectation no longer holds, as teachers are now mainly recruited from other parts of the country and may not even be aware of the existence of the Kuy as a separate ethnolinguistic group. As schooling was much more limited in the past, many of the older speakers in this sample did not complete school past fourth or sixth grade (established in 1972), as the school was not expanded to ninth grade until 1998 (EMIS 2013, p.c. Sidawun Chaiyapha). Most of the younger population in this study also attended high school nearby and continued to college. Those who continue to college are immersed in Thai by virtue of being in school longer and by living in non-Kuy speaking areas. Lao also serves as a regional lingua franca for those who come from various parts of Isan. Following college, much of the younger population proceed

to work in other regions of Thailand, where they use Thai and/or Lao. This continuing trend is facilitated by the continued rapid improvement in transportation infrastructure in Thailand. While spending time in other parts of Thailand was not uncommon in the older generation, it has become much more mainstream. From the same sample as in Tables 4 and 5, only 46.67% of women older than 45 had spent any time away from home, as opposed to 65.52% of men. Meanwhile, this gap closes for those below 45, with the proportion being 86.21% for women and 89.66% for men.

The demographic information above shows a clear generational shift in the Kuy population in this study: the younger generation is spending more time in school and in other parts of Thailand. As a result, they use much more Thai and many consider themselves to be equally bilingual in Kuy and Thai, a finding mirrored in Siebenhüttner (2020). The language dynamics are changing in Kuy society due to both the average life trajectory of a member of the Kuy community and to the distribution of languages that are now heard in the village, owing to the encroachment of Thai into more linguistic contexts. Many younger parents report using Thai, rather than Kuy, in the home with their children, with a common reason being to expose their children to Standard Thai early for the purposes of succeeding in school, and report that their children can understand, but not speak, Kuy. Due to these shifts in Kuy usage, it is currently classified by Ethnologue as 6b: Threatened (Simons & Fennig, 2017) and as “severely endangered” by UNESCO (Moseley, 2010).

If these dynamics sufficiently increase the exposure to and usage of Thai, which is tonal, we may expect f0 usage in the register contrast of Kuy to increase. There are a number of contemporary studies on language contact effects on f0 usage in the context of MSEA. Brunelle (2009) explores cues in the register contrast in three dialects of Cham, demonstrating that Eastern Cham speakers, who are highly bilingual in tonal Vietnamese, show the greatest pitch differences, although Brunelle (2005) finds that younger speakers use pitch less than older ones. In exploring the realization of Lao tones by speakers with different language backgrounds in Isan, Pratankiet (2001) finds that Khmer and Kuy speakers show citation form differences from bilingual Lao-Thai speakers, while Sipipattanakun (2014) shows that they have narrower f0 pitch ranges than those who are only bilingual in Lao and Thai. Both linguists attribute these differences to the lack of tone in Kuy and Khmer, but point out as well that differences in some tone realizations may be attributable to influence from Standard Thai.

The effect of Kuy bilingualism on the Thai tone contrast shows substrate effects on a superstrate language. Potential evidence for the reverse comes from a number of studies on the f0 contrast in Kuy. An apparent time study on three Ku(a)y varieties in Thailand and one in Laos by Sukgasame (2003) reveals that the Thai varieties are giving way to a pitch distinction and the Lao ones to a vowel quality distinction in younger speakers. In a follow-up study on two Thai varieties (one of which overlapped with Sukgasame, 2003), Sukkasame (2004) shows similarities between the emergent pitch patterns in these varieties and the tone patterns in the neighboring Lao varieties. A production and perception study by Abramson et al. (2004) finds that voice quality is a weak cue in production and perception for some Kuy speakers, while Lau-Preechathammarach (2022) demonstrated greater usage of f0 cues for Kuy speakers who use Thai or Lao more than for those who use it less at the group level in both perception and production. These studies together suggest that the Kuy register contrast may be shifting to one that employs pitch more and that this may be due to influence from Thai or Lao.

2 Hypothesis and Methods

This study delves into individual differences in the acoustic correlates of the Kuy register distinction and examines whether the interaction with language usage and other social factors found at the group level is also found at the individual level. Participants who use Thai/Lao more are hypothesized to also use f0 cues more and voice quality cues less in the register contrast, as compared to participants who do not use Thai/Lao as much. A tradeoff is also expected between f0 and voice quality cues, such that speakers who weigh f0 more heavily are expected to weigh voice quality cues less heavily. The goal of this study is to provide a close analysis of how we might understand the macro-effects of language contact on linguistic structure in language used by a community through the micro-effects of bilingualism on the realization of a phonological contrast at the individual level.

In order to test these hypotheses, a production study was carried out in which participants embedded modal and breathy minimal pairs in a carrier sentence. Following the task, speakers were interviewed to gather demographic and sociolinguistic information. Acoustic measures were taken over the course of the target vowels for analysis. Data was transformed by using a principal component analysis to highlight the most meaningful dimensions of variation. Linear regression models were then fitted to estimate the general effects of sociolinguistic factors on trajectories of the acoustic measures. Finally, a linear discriminant analysis was run to determine the acoustic cue weights for each individual and correlations between cue weights and sociolinguistic factors were analyzed to understand speaker patterns.

2.1 Participants

In Tambon Tum, there are three villages with a sizable Kuy population: Ban Khi Nak (Kuy: /tʰrɔ? kʰna:k/), Ban Rong Ra (Kuy: /tʰrɔ? ara?/), Ban Khi Nak Noi (Kuy: /tʰrɔ? ke:t/). According to Kuy speakers in Tambon Tum, these three villages speak the same variety of Kuy. 75 participants were recruited from these three villages in the Fall of 2018 with the help of Thongwilai Intanai, a Kuy speaker from Ban Khi Nak. Participants were explicitly balanced for age and gender, comprising four decades (twenties, thirties, fifties, and sixties) and two genders (female and male). At least eight speakers were sought for each age-gender combination, but given time constraints, extra speakers were also recruited opportunistically, such that some subgroups are overrepresented. Ultimately, nine speakers were excluded from analysis due to failing to complete the experiment (one), extreme difficulty with the task (two), recording issues (four), and producing fewer than ten analyzable (see §2.5 for determination of analyzability) unique words (two), leaving 66 participants (40 from Ban Khi Nak, 14 from Ban Rong Ra, and 12 from Ban Khi Nak Noi). These participants' ages (subgrouped by decade) and genders are provided in Table 6.

Table 6: Participants by age and gender

	20s	30s	50s	60s
F	8	8	10	8
M	8	8	7	9

A sociolinguistic questionnaire, a translated version of which may be found in Appendix D, designed to capture factors related to language ability, language usage frequency, time spent away from home, and ethnolinguistic affiliation, was administered in Thai following the experimental portion of the study. All speakers are bilingual in Kuy and Thai and most have at least some

knowledge of Lao and Khmer. Only one participant reports not understanding Lao, while six report not understanding Khmer. In terms of speaking ability, three participants report not being able to speak Lao, while 16 report not being able to speak Khmer. All participants are able to read and write Thai, although some older participants have more difficulty doing so. While 20 participants (almost one-third) report never having lived outside of Tambon Tum, there is a fair spread in the time spent away for the remaining 46 participants. The mean and median number of years spent away from home are 5.7 and 4, respectively, while the minimum (non-zero value) and maximum numbers are 0.5 and 47, respectively. There is a considerable amount of variation in language usage and ability and in time spent away from home. It is the relationship between this variation and manifestation of the acoustic correlates of register that the current study seeks to probe.

2.2 Stimuli

The stimuli for the experiment included 58 unique words, consisting of 31 target words and 27 distractor tokens (see Appendix A). The target words comprised 12 modal unaspirated vs. breathy pairs, 2 modal aspirated vs. breathy pairs, and 1 modal unaspirated vs. modal aspirated vs. breathy triplet. Of the target words, 4 potentially contain syllabic nasals in the first syllable. In creating this wordlist I attempted to elicit as many minimal pairs(/triplets) as possible, with the help of a dictionary by Sriwises (1978) and a Kuay wordlist from Abramson et al. (2004). However, the resulting list was limited and so words were balanced only for voice quality, but not for segments. I recognize that the imbalance of voice quality may be a confound as phonation differences tend to be greater in low vowels (Kuang & Cui, 2018; Brunelle et al., 2020). The remaining distractor tokens were chosen to observe phenomena for future research: (1) the syllabic nasal (2) the ongoing /tr/ ~ /kr/ merger, and (3) the ongoing coda /r/ ~ /l/ merger. These variables show similar variation in other Ku(a) varieties (Sukkasem, 2005, p. 50).

2.3 Procedure

The task in the current production study involved embedding the stimuli in a carrier sentence. The sentence was presented in Thai primarily because Kuy orthography is recently developed and few speakers are familiar with it³, but secondarily to avoid reading pronunciation. The example sentence presented to participants is in (1). In order to facilitate naturalness, participants were asked to translate this sentence into Kuy and to use that frame for each sentence, only replacing the word “water” with the stimulus. One common translation of the sentence is in (2). Differences mainly lay in presence or absence of the complementizer /paj/ ‘say’ and uses of synonyms, such as /kʰam/ for /pna:j/ or /pa:j/ for /waw/. The stimulus retained prominence regardless of the sentence used. The experiment was presented to participants on a Google Nexus 10 tablet and carried out in a quiet room in the temple of Wat Nakharin in Ban Khi Nak. Participants were recorded using an AKG C544-L head-worn condenser microphone connected to an H4n Zoom recorder. Pictures were included with each sentence to aid in elicitation of the intended word. Figure 2 shows the screen that participants saw for the example sentence with “water”, while Figure 3 shows what participants saw for the trial sentence with “egg”.

- (1) Example Thai sentence

ฉัน พูด คำ ว่า นำ ให้ เขา 听
 cʰān pʰū:t kʰām wâ: ná:m hâj kʰǎw fāŋ
 1SG say word COMP⁴ water for 3 hear

‘I say the word “water” for them to hear.’

- (2) Example Kuy translation (in Mahidol orthography)

ໄຊ ເວ ປະນາຍ ໄປ ເດືອະ ອອຸນ ໙າ ຈະງັດ
haj waw pna:j paj dia? a:n naw cnat
1 say word COMP water for 3 hear
‘I say the word “water” for them to hear.’



Figure 2: Example sentence in (1). Instructions above say “Please translate the following sentence into Kuy”. The example Thai word /ná:m/ ‘water’ is in red.

Figure 3: Example sentence from task. The example word /ná:m/ ‘water’ has been replaced with /kʰàj/ ‘egg’ (in red). The expected Kuy word is /ntr̥ɛ:l/.

In the training round, the participant first settled on an appropriate translation for the sentence in (1). We then went through each stimulus once as a practice round for familiarization. The participant then completed five rounds alone (generally taking between 15 and 30 minutes in total), with an optional break after the third round. Stimuli were randomized in each round. Participants were told that they could skip a word if they could not remember it. As there were 31 target words and five rounds, 155 targets words in total could theoretically be produced.

2.4 Preprocessing of sociolinguistic information

Principal component analysis (PCA) is a technique used to reduce a number of variables to a small number of orthogonal dimensions that capture variance between the variables and is particularly useful when variables are expected to be highly correlated with each other. As much of the sociolinguistic information was expected to be correlated to language usage, a PCA was carried out using the FactoMineR package (Lê et al., 2008) in R (R Core Team, 2018) to reduce the data to a tractable number of variables for analysis. Many of the variables (see Appendix D) involved frequency of usage or level of ability/identification, all with respect to the 4 languages/ethnic groups in the area. As such, this data was first consolidated by calculating differences between answers with respect to Kuy and to the tonal languages, Thai/Lao, rather than taking the reported values at face value for two reasons. First, participants differed in how “humble” they were with their answers. For example, some participants rank their ability as low in even their most comfortable language, while others are more “confident”. Second, the goal was to yield a proxy

Table 7: Sociolinguistic Variables for PCA

Factor	Description
Age	Participant's age in years.
√Years Away	Square root of years spent living in another (non-Kuy speaking) area.
Understand	Sum of ability to understand Kuy and Khmer (each coded from 0-4) minus sum of ability to understand Thai and Lao (each coded from 0-4).
Speak	Sum of ability to speak Kuy and Khmer (each coded from 0-4) minus sum of ability to speak Thai and Lao (each coded from 0-4).
Overall Freq	Sum of overall frequency of using Kuy and Khmer (each coded from 0-100) minus sum of overall frequency of using Thai and Lao (each coded from 0-100).
Family Freq	Sum of frequency of using Kuy and Khmer with family (each coded from 0-100) minus sum of frequency of using Thai and Lao with family (each coded from 0-100).
Friend Freq	Sum of frequency of using Kuy and Khmer with friends (each coded from 0-100) minus sum of frequency of using Thai and Lao with friends (each coded from 0-100).
ID	Sum of self-rating of Kuy and Khmer identity (each coded from 0-3) minus sum of self-rating of Thai and Lao identity (each coded from 0-3).

measure that would capture the *relative* level of Kuy usage/ability/identification *as compared to* Thai/Lao. Since there is a heavy right skew for the number of years away people have spent away from home (mean: 5.7, median: 4, skew: 3.12⁵), the number of years was square rooted, yielding a new, less skewed distribution (mean: 1.84, median: 2, skew: 0.57). The transformed sociolinguistic variables that were input into the PCA are explained in Table 7. Values were scaled by dividing z-values by two, following Gelman (2008), who proposes this method for statistical modeling to allow for direct comparison with binary predictors.

2.5 Acoustic Analysis

Following forced alignment on the production results using the Montreal Forced Aligner (McAuliffe et al., 2017), target vowel boundaries were realigned and, for stops, the voice onset time (VOT) boundaries were marked by myself and twelve undergraduate research assistants. For each token, eight acoustic measures were taken over the course of the target vowel using VoiceSauce, a software for calculating voice measures (Shue et al., 2011). These measures are f0, F1, CPP, and five harmonic measures (H_1^* , $H_1^* - H_2^*$, $H_1^* - A_1^*$, $H_1^* - A_2^*$, $H_1^* - A_3^*$). CPP, *cepstral peak prominence*, is a proxy for *harmonics-to-noise ratio* (HNR). Breathier voice qualities have lower HNR and CPP values (Hillenbrand et al., 1994). H_n refers to the amplitude of the n^{th} harmonic, while A_n refers to the amplitude of the loudest harmonic in the n^{th} formant. $H_1 - H_2$ correlates with *open quotient*, the ratio of the glottal cycle for which the vocal folds are open, while the $H_1 - A_n$ values are measures of *spectral tilt*, the rate of the loss of energy as the frequency of harmonics increase. Higher open quotients and steeper spectral tilt are associated with a breathier voice quality (Holmberg et al., 1995; Hanson, 1995, 1997; Hanson & Chuang, 1999; Henrich et al., 2001; Gobl & Ní Chasaide, 2013). The asterisks following the spectral measures indicate correction for formant frequencies and bandwidths and in order to account for individual differences

between speakers (Iseli et al., 2007). All of the spectral tilt measures were ultimately combined into one, to be called $H_1^*(-A_n^*)$, through a PCA on the five harmonic measures and CPP (see §3.2). Ultimately, five measures remained for analysis: f0, F1, CPP, $H_1^*-H_2^*$, and $H_1^*(-A_n^*)$.

Files were marked for whether the uttered word was the intended target and, for the four words with potential syllabic nasals, whether the nasal was existent (determined by looking for evidence of nasalization in the spectrogram). Minimal pairs were included in the analysis only if the speaker produced at least two tokens of each member of the pair and only if the tokens for each member of the pair matched in presence or absence of the syllabic nasal. For most pairs, this meant that the word with the potential syllabic nasal had to lack it (ex. /⟨n⟩cʰu:n/ ‘to hide’ and /cu:n/ ‘to send’), but in the case of /⟨ŋ⟩ke:ŋ/ ‘waist’ vs. /⟨ŋ⟩ke:ŋ/ ‘side’, the pair was included only if both words had at least two tokens matching in presence or absence of the nasal. Following this procedure, 5125 files were available for analysis.

Because voice tracking algorithms are sensitive to individual differences, f0 and the first three formants were calculated with speaker-specific parameters. f0 was tracked with the STRAIGHT algorithm (Kawahara et al., 1998) through VoiceSauce. Pitch halving and pitch doubling errors were identified and the pitch floor and ceiling were adjusted accordingly. Formants were measured with Praat (Boersma, 2001), also through VoiceSauce. For participants whose f0 values averaged below 150 Hz, the formant ceiling was set at 5500 Hz and the number of formants to be detected was set at 5.5, while for those whose f0 values averaged above 150 Hz, these values were set at 5000 Hz and 4.5, respectively, following heuristics laid out by Skarnitzl et al. (2015). After inspection, the ceiling was shifted as necessary to minimize errors. These f0 and formant values were the basis for VoiceSauce’s calculation of the five harmonic measures and CPP. All measurements were taken at every millisecond with a sliding window of 25 ms.

Three more steps were implemented to handle errors following extraction of results with VoiceSauce. First, a moving median filter with a size of 15 ms was applied to smooth out sudden tracking jumps. Second, zero values (0.1% of the dataset) were removed. Finally, z-scores were calculated, using the means and standard deviations for each combination of speaker \times vowel quality \times voice quality, and values greater than 3 standard deviations away from the mean (5.2% of the remaining dataset) were removed, minimizing tracking jumps that persisted for longer than the median filter window. Ultimately, 5.29% of the dataset was removed. Because individuals speak at different rates and vowels vary in their length, time was normalized by binning measurements for each file into twenty time intervals and calculating the mean value at each interval. As voice quality measures vary largely across individuals (Biever & Bless, 1989; Klatt & Klatt, 1990; Linville, 1992; Hanson, 1995, 1997; Hanson & Chuang, 1999; Linville, 2002; Davies & Goldberg, 2006; Ma & Love, 2010; Lee et al., 2015), the values were scaled by speaker, with Gelman’s 2008 standardization procedure (see §2.4), for comparability and statistical modeling. For F1, the values were additionally scaled by vowel height. f0 and F1 Hertz values were also converted into semitones⁶ to better approximate auditory distance (Nolan, 2003).

In order to explore group differences and the overall relationship between sociolinguistic factors and the voice quality measures, linear mixed effects regression models were fitted for the scaled values of each voice quality measure with the lme4 (Bates et al., 2015) package in R. The model looked at the effect of the interaction of Timepoints (modeled with B-splines using three knots to capture smooth curves with knots at arbitrary timepoints (Curry & Schoenberg, 1966)), Register, Gender, Tonal Language Experience, and Time Away (see §3.2 for an explanation of the last two predictors) on the five acoustic measures (f0, F1, CPP, $H_1^*-H_2^*$, $H_1^*(-A_n^*)$). The maximal model for each measure yielded the lowest Akaike Information Criterion (AIC), so all interactions were kept. Random intercepts were included for Speaker and Word, but random slopes were not included as they led to overfitting.

Individual differences were then explored by quantifying cue weights for f0, F1, $H_1^* - H_2^*$, $H_1^*(-A_n^*)$, and CPP through the use of Linear Discriminant Analysis (LDA), a technique that involves training a classifier to categorize stimuli into classes given a set of information and labels for that information. LDA, carried out through the `scikit-learn` library in Python 3.7 (Van Rossum & Drake, 2009) is the method of choice as it has been shown to be a robust technique for approximating cue weights and therefore is useful for analyzing individual differences in both production and perception studies (Idemaru et al., 2012; Schertz et al., 2015; Schertz & Clare, 2020). The data fed into the LDA was each acoustic measure at each of the 20 time bins for each token. The training and test process involved k -fold cross-validation, in which the dataset is split into k folds, or equal subsets, whose size is $\frac{n}{k}$ rounded up or down to the nearest integer as necessary, where n is the size of the dataset. Each of these subsets comprises a test set, while the subset of tokens that excludes the test subset comprises the training set. The classifier is trained on each training set and then applied to the test set. The resulting classification for the test subset is compared to the actual classification to yield an accuracy score. In this study, a classifier was trained, for each individual, to determine whether each token was *modal* or *breathy*, given the acoustic measures for the token. As in the linear regression analyses, the scaled values for all the measures are used. Semitones are used for f0 and F1. A combined accuracy for all phonation measures ($H_1^* - H_2^*$, $H_1^*(-A_n^*)$, CPP), henceforth called Voice Quality (VQ), was also obtained by providing the LDA classifier information from these three measures combined. 10-fold cross-validation was used and the mean of the 10 results was calculated as a proxy for the cue weight of each measure. Pearson's r was calculated between these cue weights and Tonal Language Experience to test whether there was a correlation between language usage and production cue weights. Correlations between f0 and the other cue weights were also calculated in order to test whether there is a tradeoff between f0 and other register cues.

3 Results

3.1 Summary Statistics

Of the 5125 files, 4542 contained a target word with a stop onset. The means and standard deviations of the voice onset time (VOT) of these stops are summarized in Table 8 and visualized in Figure 4. While the VOT of breathy vowels sits between those of modal vowels following un aspirated stops and modal vowels following aspirated stops, it is much closer to the former (+ 10 ms) than the latter (-40 ms).

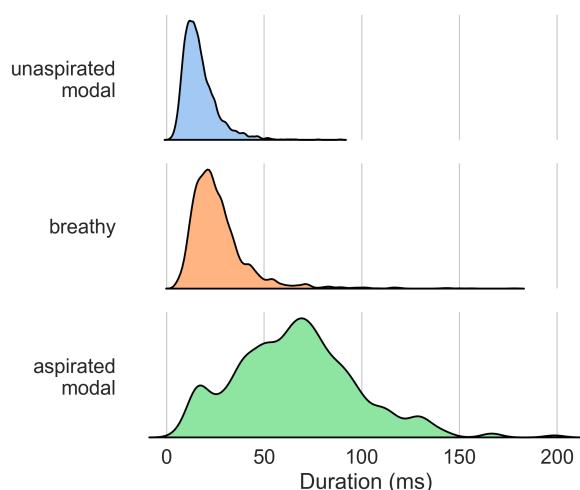


Table 8: Mean VOT durations (ms)

Stop type & Register	Mean	SD	n
Unaspirated modal	17	9	1938
Breathy	27	16	2262
Aspirated modal	66	31	342

Figure 4: VOT means by stop type and register 13

Table 9 and Figure 5 break down and visualize the means and standard deviations of vowel durations from the data by vowel and voice quality. Scaled values are used because of interspeaker differences. Short breathy vowels are longer than modal ones (note, however, that there are only two short vowel pairs), matching the generalization that breathy vowels tend to be longer than modal ones, but long vowels do not have a consistent pattern. This inconsistency matches the findings of L. Thongkum (1989) for Kuy, who suspects that the durational difference between registers may not occur robustly in languages with a vowel length contrast.

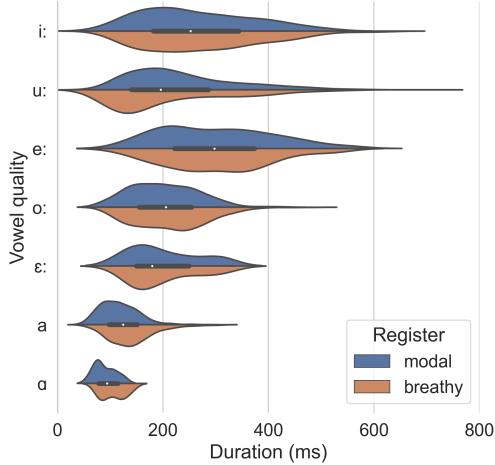


Table 9: Mean vowel durations (ms)

Vowel	Modal			Breathy		
	Mean	SD	n	Mean	SD	n
i:	263	106	447	278	111	429
u:	236	102	718	212	114	733
e:	302	107	228	305	98	211
o:	201	65	440	215	68	430
ε:	202	66	61	201	63	55
a	116	36	639	141	45	648
ɑ	89	20	48	106	23	38
Overall	207	104	2581	211	105	2544

Figure 5: Duration by vowel quality

Figures 6 shows mean f0, $H_1^* - H_2^*$ (a robust correlate of voice quality), and F1 trajectories and 95% confidence intervals for each vowel. Scaled values (described in 2.5) are used to normalize for interspeaker and vowel quality (in the case of F1) differences. Confidence intervals for /ε:/ and /ɑ/ are large because they are represented by few tokens. While some register languages, such as Arem (Tä, 2021), show f0 differences in only some vowels, it is clear that modal voice is higher overall than breathy voice in Kuy, regardless of vowel quality.

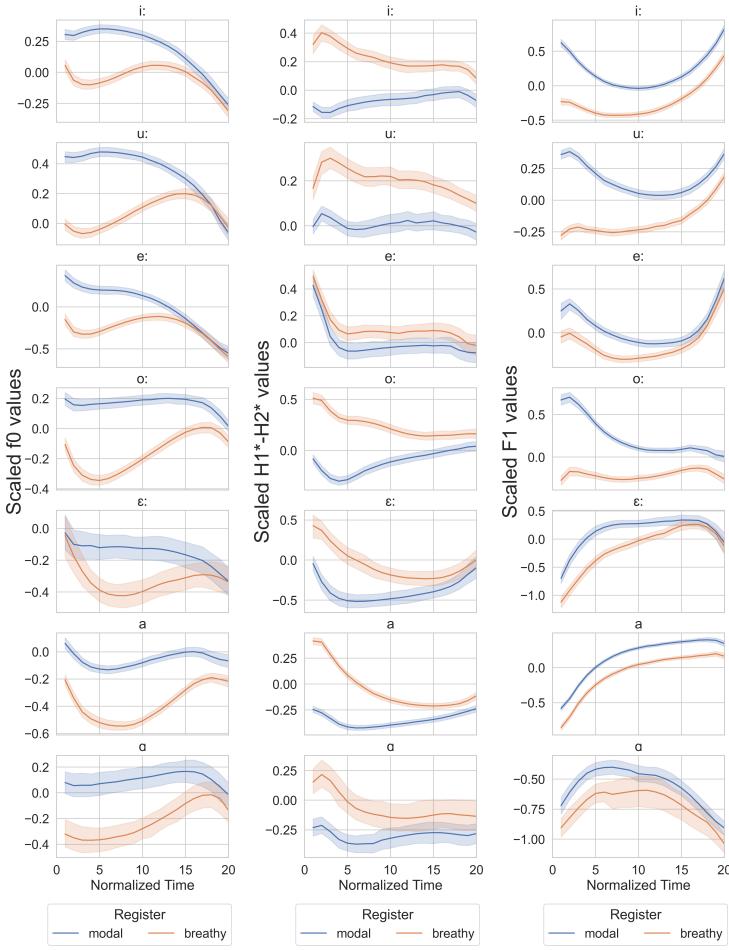


Figure 6: f_0 , $H_1^* - H_2^*$, & F_1 trajectories by vowel quality

Table 10: Mean f_0 , $H_1^* - H_2^*$, & F_1 values by vowel quality & register

Vowel	f_0 (Hz)	
	Modal	Breathy
i:	174.96	169.16
u:	179.95	170.98
e:	167.92	161.34
o:	175.17	166.46
ε:	176.86	167.8
a	170.28	161.99
ɑ	192.15	184.38

Vowel	$H_1^* - H_2^*$ (dB)	
	Modal	Breathy
i:	8.08	9.95
u:	8.51	9.55
e:	8.66	9.41
o:	7.9	10.42
ε:	5.58	8.05
a	5.91	7.99
ɑ	6.55	8.69

Vowel	F_1 (Hz)	
	Modal	Breathy
i:	387.54	350.11
u:	379.53	351
e:	450.1	428.26
o:	470.91	424.19
ε:	600.81	567.13
a	926.32	881.34
ɑ	703.97	649.68

3.2 PCA results on social variables and acoustic correlates of voice quality

Correlations between the social variables, the percentage of variance explained by each dimension in the PCA, and correlations between each dimension and each social variable may be found in Appendix B. The first dimension captures 36.7% of the variance and is primarily contributed to by most of the sociolinguistic variables except for frequency of Kuy usage with one's own family and time spent away. Dimension 1 appears to capture ability and frequency of Kuy usage, alongside age, which is unsurprisingly correlated with the former two factors, given the generational shift away from using Kuy. This dimension could be called *Kuy Experience*. However, as the hypothesis is related to usage of a tonal language (i.e. Thai and Lao in this case), this dimension will be negated and referred to as *Tonal Language Experience* (TLE) for ease of interpretation. The remaining dimensions are either primarily comprised of variables that are difficult to cohesively interpret or explain too little of the variance to justify using in the analysis, so they will not be incorporated into the analysis. However, as this study is also interested in the effect of time spent living in non-Kuy speaking areas, the factor $\sqrt{\text{Years Away}}$ will be employed in the analysis and will be referred to simply as *Time Away*.

Correlations between the voice quality variables, the percentage of variance explained by each dimension in the PCA, and correlations between each dimension and each voice quality variable

may also be found in Appendix B. Dimension 1 captures 41.86% of the variance and is primarily contributed to by all H_1^* -related values *except* for $H_1^* - H_2^*$. This variable will be called $H_1^*(-A_n)$. The remaining dimensions will not be used as Dimension 2 is comprised mainly of CPP, Dimension 3 of $H_1^* - H_2^*$, and the rest account for little variation. Because CPP and $H_1^* - H_2^*$ do not load much on to Dimension 1, they will be treated as separate variables in the analysis.

3.3 Linear Model Results

Values for the dependent variable for each register at twenty time intervals over the vowel, given values of Tonal Language Experience and Time Away 1.5 standard deviations above and below the mean, were estimated by feeding the linear regression models from 2.5 into the effects package in R (Fox & Hong, 2009). There is significant 5-way interaction between Timepoints, Register, Gender, TLE, and Away on f0 ($p < .05$ at Time 1, $p < .001$ at Times 2 and 3), $H_1^*(-A_n^*)$ ($p < .01$ at Times 2 and 3), and CPP ($p < .001$ at Time 2, $p < .05$ at Time 3). On $H_1^* - H_2^*$, there is a significant 4-way interaction between Timepoints, Register, Gender, and TLE ($p < .01$ at Times 1 and 2, $p < .001$ at Time 3) and between Timepoints, Register, TLE, and Away ($p < .01$ at Time 1, $p < .001$ at Time 3). On F1, there is a significant 4-way interaction between Timepoints, Register, Gender, and TLE ($p < .001$ at Times 1 and 3, $p < .01$ at Time 2).⁷ The linear regression table for each dependent variable may be found in Appendix C. In order for readers to grasp the magnitudes of the differences, the estimated scaled values were converted back to the original unit by using raw group means and standard deviations for each gender. The back-converted values are calculated by multiplying the estimated scaled value by two times the group standard deviation and adding the group mean. Semitones are converted to Hz. These values are visualized in Figures 7 through 11. $H_1^*(-A_n^*)$ is not reconverted as it is a principal component comprising multiple factors but kept in “half standard deviation” units, as per the scaling method in Gelman (2008). F1 is also displayed in scaled units as the values differ by height. Table 11 quantifies the mean difference between modal and breathy trajectories for each measure in Figures 7 through 11. These mean differences will be referred to as F for female participants and M for male participants.

Differences will be discussed for each measure in turn. Figures 7 through 9 may each be thought of as representing eight theoretical speakers of the stated gender who would have a TLE score 1.5 standard deviations below (the “less TLE” row) or above (the “greater TLE” row) the mean and who would have spent time away equivalent to 1.5 standard deviations below (the “less Time Away” column) or above (the “greater Time Away” column) the mean: (1) The lower left grids in each figure represent a female and male speaker, to be called the “conservative speakers”, who use Kuy, with respect to Thai/Lao, more frequently and/or proficiently than other members of the community and have spent little to no time away from home. (2) The upper left speakers have also spent little to no time away from home, but use Kuy, with respect to Thai/Lao, less frequently and/or proficiently than other members of the community. (3) The lower right speakers use Kuy, with respect to Thai/Lao, less frequently and/or proficiently than other members of the community, but have spent much time away from home. (4) Finally, the upper right speakers both uses Kuy, with respect to Thai/Lao, less frequently and/or proficiently than other members of the community and have also spent much time away from home. For Figures 10 and 11, the bottom speakers would be “more conservative” than the top one. 95% confidence intervals are included for each trajectory.

Table 11: Average differences in predicted means between modal and breathy voice

Measure	Vowel Height	Female				Male				
		↓Away		↑Away		↓Away		↑Away		
		Units	Scaled	Units	Scaled	Units	Scaled	Units	Scaled	
f0	↑TLE	13.1 Hz	.47	12.55 Hz	.45	5 Hz	.27	5.22 Hz	.27	
	↓TLE	3.37 Hz	.12	5.42 Hz	.19	4.2 Hz	.22	6.06 Hz	.32	
CPP	↑TLE	2.40 dB	.33	1.46 dB	.2	2.63 dB	.34	.91 dB	.12	
	↓TLE	1.01 dB	.14	1.07 dB	.15	.55 dB	.07	.98 dB	.13	
$H_1^* (- A_n^*)$	↑TLE		-.26		-.14		-.5		-.25	
	↓TLE		-.3		-.36		-.27		-.32	
Female										
		Units	Scaled		Units		Scaled			
$H_1^* - H_2^*$		↑TLE	-.35 dB		-.04		-3.4 dB		-.55	
		↓TLE	-1.81 dB		-.22		-1.5 dB		-.24	
F1	high	↑TLE	32.25 Hz		.36		16.65 Hz		.22	
		↓TLE	27.57 Hz		.31		30.19 Hz		.4	
	mid-high	↑TLE	42.67 Hz		"		18.83 Hz		"	
		↓TLE	36.55 Hz		"		34.18 Hz		"	
	mid-low	↑TLE	47.06 Hz		"		21.65 Hz		"	
low	↓TLE	40.17 Hz		"		39.34 Hz		"		
	↑TLE	88.61 Hz		"		31.43 Hz		"		
low	↓TLE	75.87 Hz		"		57.11 Hz		"		

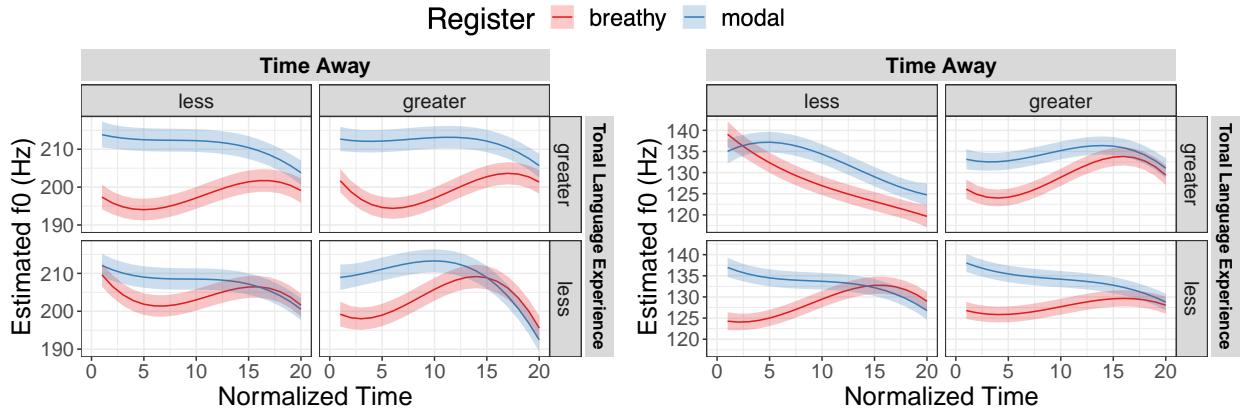


Figure 7: Estimated f0 trajectories for female (left) and male (right) speakers

For both female and male speakers, less Tonal Language Experience (TLE) and less Time Away yield the smallest f0 differences between modal and breathy voice, although they are still significantly different in the expected direction (F: 3.37 Hz; M: 4.2 Hz). For female speakers, greater TLE is correlated with a notable increase in f0 differences but more Time Away is only correlated with larger f0 differences in the speaker with lower TLE. Meanwhile, for male speakers, greater Time Away is correlated with a modest increase in f0 differences. The largest f0 difference between the registers is seen in the greater TLE, less Time Away female speaker at 13.1 Hz. This value is 9.73 Hz greater than the one for the conservative speaker. The largest difference for male speakers is seen in the lower TLE, greater Time Away combination at 6.06 Hz, which is 1.86 Hz greater than for the conservative speaker. A noteworthy effect is that greater TLE correlates with the f0 differences between the registers being maintained over more (and as much as all) of the vowel. More Time Away also appears to correlate with increased duration of differences, if TLE is low.

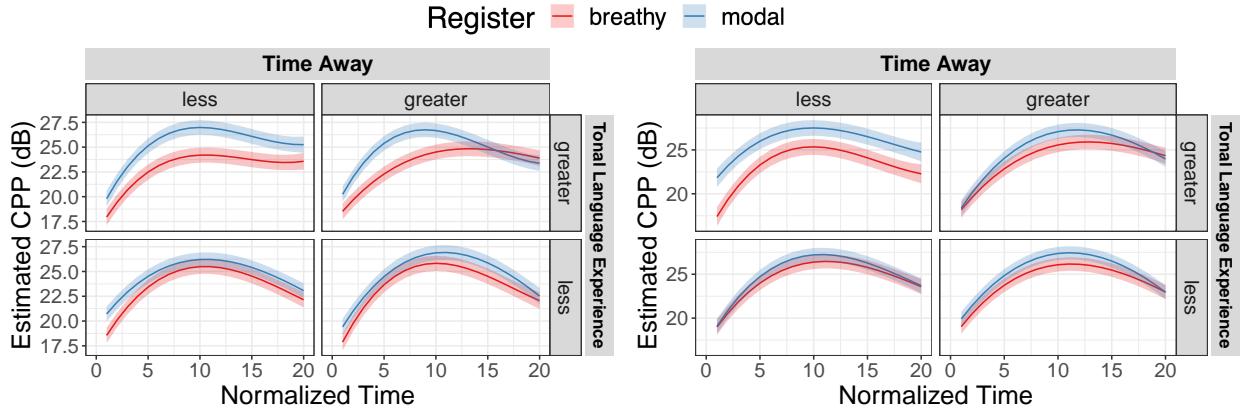


Figure 8: Estimated CPP trajectories for female (left) and male (right) speakers

CPP shows a similar pattern to f0 in that the smallest differences are seen with less TLE and less Time Away (F: 1.01 dB; M: 0.55 dB). For female speakers, an increase of TLE correlates with greater CPP differences between the registers. For both female and male speakers, the greater TLE, less Time Away combination yields the largest differences (F: 2.4 dB, M: 2.63 dB), with the differences persisting over most or all of the whole vowel, like f0. These values are 1.39 dB and 2.08 dB greater than the values for the conservative speakers. Time Away shows mixed differences.

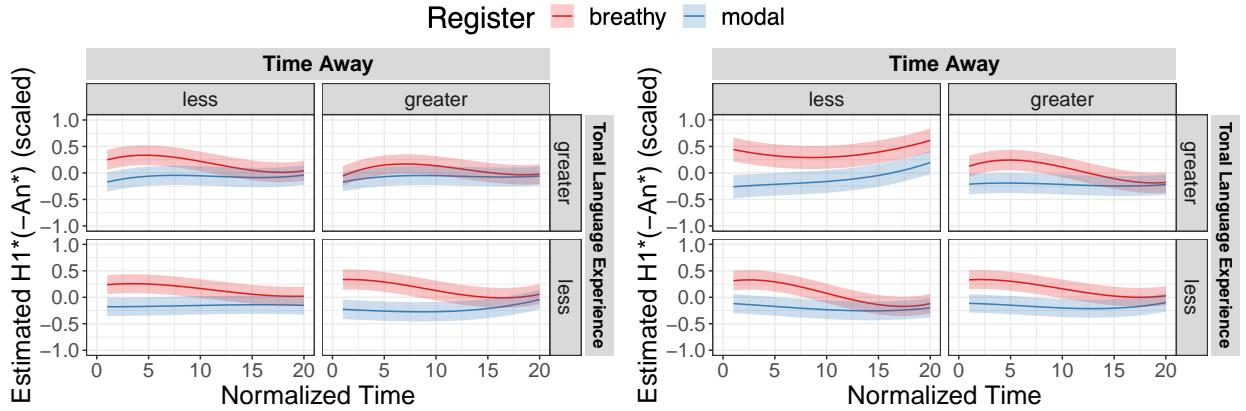


Figure 9: Estimated $H_1^*(-A_n^*)$ trajectories for female (left) and male (right) speakers

For female speakers, the largest $H_1^*(-A_n^*)$ differences are seen in the less TLE, greater Time Away combination (-0.36 scaled units) but for male speakers, they are in the greater TLE, less Time Away combination (-0.5 scaled units). An increase in TLE corresponds to a decrease of differences between the registers for female speakers, but there is no clear pattern for male speakers.

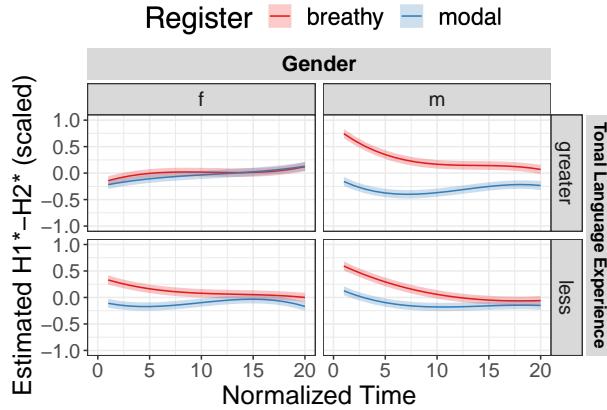


Figure 10: Estimated $H_1^* - H_2^*$ trajectories

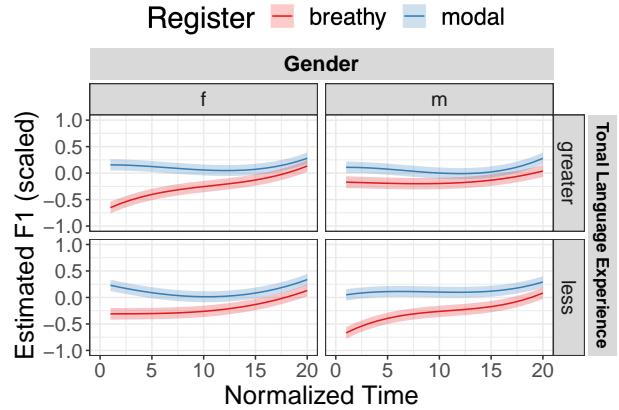


Figure 11: Estimated F1 trajectories

$H_1^* - H_2^*$ differences are smaller for female speakers with greater TLE (-.35 dB) than those with less (-1.81 dB), while male speakers show the opposite pattern as speakers with greater TLE actually have *larger* differences (-3.4 dB) than those with less (-1.5 dB).

F1 differences between the registers will be discussed in terms of scaled units, as these are the same regardless of height. While female speakers with greater TLE show similar F1 differences to those with less TLE (.36 scaled units vs. .31 scaled units), male speakers with greater TLE show smaller F1 differences than those with less (.22 scaled units vs. .4 scaled units).

3.3.1 Summary of group differences

The results reveal a mixed and complicated interaction between the sociolinguistic factors of TLE and Time Away and the various correlates of the modal and breathy registers. However, a number of patterns arise.

For f0, greater TLE shows a clear correlation with *increased differences* between the registers for female speakers. More Time Away is correlated with greater f0 differences for male speakers, while for female speakers, it only correlates with increased f0 differences for the low TLE speaker. Greater TLE is also correlated with the f0 difference persisting over more of the vowel for both female and male speakers. The positive correlation of TLE with f0 differences for female speakers corroborates the hypothesis, as does the positive correlation of Time Away with f0 differences for male speakers, although the magnitude is small for the latter. Greater TLE and Time Away does seem to correlate with greater persistence of f0 differences over the vowel, however.

Greater TLE correlates with smaller $H_1^* - H_2^*$ and $H_1^*(-A_n^*)$ differences for female speakers, while Time Away has mixed effects. For male speakers, TLE correlates with larger $H_1^* - H_2^*$ differences. The decreased $H_1^* - H_2^*$ and $H_1^*(-A_n^*)$ differences for female speakers with greater TLE align with the hypothesis, as voice quality cues are weakened. For male speakers however, the increase of $H_1^* - H_2^*$ with greater TLE is opposite from the expectation. Greater TLE is also correlated with increased differences in CPP between the registers for female speakers. The correlation of greater TLE with larger CPP differences, at least for female speakers, however, runs contrary to the hypothesis.

Smaller F1 differences are seen with an increase in TLE for male speakers, while female speakers show little difference. The decrease for male speakers aligns with the hypothesis.

In sum, the hypothesis that f0 differences are increased by greater usage of Thai/Lao and more Time Away is supported by the results for male speakers, but only the effect of TLE is supported

for female speakers. With respect to the effect of these factors on decreasing the weight of other voice quality measures, the results for H_1 -related measures for female speakers and F1 for male speakers corroborate the hypothesis with respect to greater usage of Thai/Lao. Time Away also decreases differences in all the cues for high TLE female speakers. Contrary to the hypothesis, TLE is correlated with greater $H_1^* - H_2^*$ differences for male speakers.

3.4 Individual differences

The accuracy scores of the LDA classifier for each of the five acoustic measures (f_0 , $H_1^* - H_2^*$, $H_1^*(-A_n^*)$, CPP, F1) and the combined VQ measure are treated as proxies for *cue weights* in the following analyses. A value of 0.5 for a given cue would mean that the LDA performed at chance (50%) in classifying register using only information from that cue, suggesting that the cue is completely uninformative in the contrast, while a value of 1 would mean that the LDA performed perfectly, meaning that the cue is maximally informative. Table 12 enumerates the number of speakers for which each cue is strongest, split by TLE (less TLE: < 0 , more TLE: ≥ 0), while Table 13 also includes the combined VQ measure. With the VQ cues split up as in Table 12, we can see that the most important cue for lower TLE speakers in general is F1, but is f_0 for female speakers and $H_1^* - H_2^*$ for male speakers with greater TLE. Table 13 shows that all the VQ cues combined are more informative than f_0 and F1 for a little more than half of the speakers (39 out of 66). For speakers with less TLE, f_0 is the strongest cue for only two speakers, but for those with greater TLE, f_0 is the strongest cue for the plurality of female speakers. Interestingly, $H_1^* - H_2^*$ is a stronger cue than the combined VQ cue for two male speakers; this could be because the non- $H_1^* - H_2^*$ phonation measures are uninformative (for the first speaker, the accuracy of $H_1^* - H_2^*$ is 0.795 while that of VQ is 0.794, while for the second speaker, they are 0.676 and 0.666, respectively, so the differences are small).

Table 12: Register cue with highest weight (excluding combined VQ measure) by number of speakers, split by TLE

Cue	F		M	
	Less TLE	More TLE	Less TLE	More TLE
f_0	2	9	3	2
$H_1^* - H_2^*$	3	1	4	12
$H_1^*(-A_n^*)$	4	1	2	1
CPP	0	1	0	0
F1	7	6	7	1

Table 13: Register cue with highest weight (including combined VQ measure) by number of speakers, split by TLE

Cue	F		M	
	Less TLE	More TLE	Less TLE	More TLE
f_0	2	8	1	2
F1	4	3	5	0
$H_1^* - H_2^*$	0	0	1	1
VQ	10	7	9	13

Two hypotheses were tested with the results of the LDA:

- (1) Higher TLE and greater Time Away are correlated with stronger f0 cue weights and weaker VQ weights
- (2) There is a tradeoff between f0 and VQ cues

To test hypothesis (1), Pearson's r was calculated between each register cue weight and TLE, as well as Time Away. No correlations with Time Away were significant, so these results are not displayed at all. Correlations between each cue and TLE are displayed in Table 14. TLE is significantly positively correlated with f0 ($r = .52, p < .001$) and CPP ($r = .4, p < .05$) accuracy, and negatively correlated with $H_1^* - H_2^*$ ($r = -.35, p < .05$) and $H_1^*(-A_n^*)$ ($r = -.34, p < .05$) accuracy for female speakers. For male speakers, TLE is significantly positively correlated with $H_1^* - H_2^*$ ($r = .5, p < .01$) and VQ ($r = .45, p < .05$) accuracy, but negatively correlated with F1 ($r = -.38, p < .05$) accuracy.

Table 14: Correlations between LDA accuracy of acoustic cue and TLE

Measure	F			M		
	r	p	Sig. ⁸	r	p	Sig.
f0	.52	.001	**	.04	.838	
$H_1^* - H_2^*$	-.35	.041	*	.5	.004	**
$H_1^*(-A_n^*)$	-.34	.048	*	.05	.791	
CPP	.4	.018	*	.14	.445	
F1	.28	.108		-.38	.032	*
VQ	-.26	.136		.45	.01	*

To test (2), Pearson's r was first calculated between f0 and each voice quality cue, the results of which are presented in Table 15. The only significant relationships are a negative correlation between f0 and $H_1^* - H_2^*$ ($r = -.54, p < .01$) and between f0 and VQ ($r = -.43, p < .05$) for female speakers. All correlations are visualized in Figure 12, with a thick black line and surrounding grey shaded region representing the regression line and a 95% confidence interval for the one significant correlation. The thin black diagonal line ($y = x$) is the identity line—speakers below this line have more accurate f0 scores than the compared acoustic cue, while those above the line have more accurate scores for the compared acoustic cue than for f0. One clear pattern is that female speakers under the identity line are better represented by those with greater TLE (those who lie on the red, rather than blue, end of the spectrum) in *all* the cue comparisons. Male speakers, however, have the opposite pattern when comparing f0 to $H_1^* - H_2^*$: most red speakers lie above the identity line, while those under the identity line are mostly blue.

Table 15: Correlations between f0 and each voice quality cue

Comparison	F			M		
	r	p	Sig.	r	p	Sig.
f0 : $H_1^* - H_2^*$	-.54	.001	**	-.04	.816	
f0 : $H_1^*(-A_n^*)$	-.21	.229		.24	.186	
f0 : CPP	-.15	.41		.14	.452	
f0 : F1	.02	.913		.29	.105	
f0 : VQ	-.43	.01	*	0	.981	

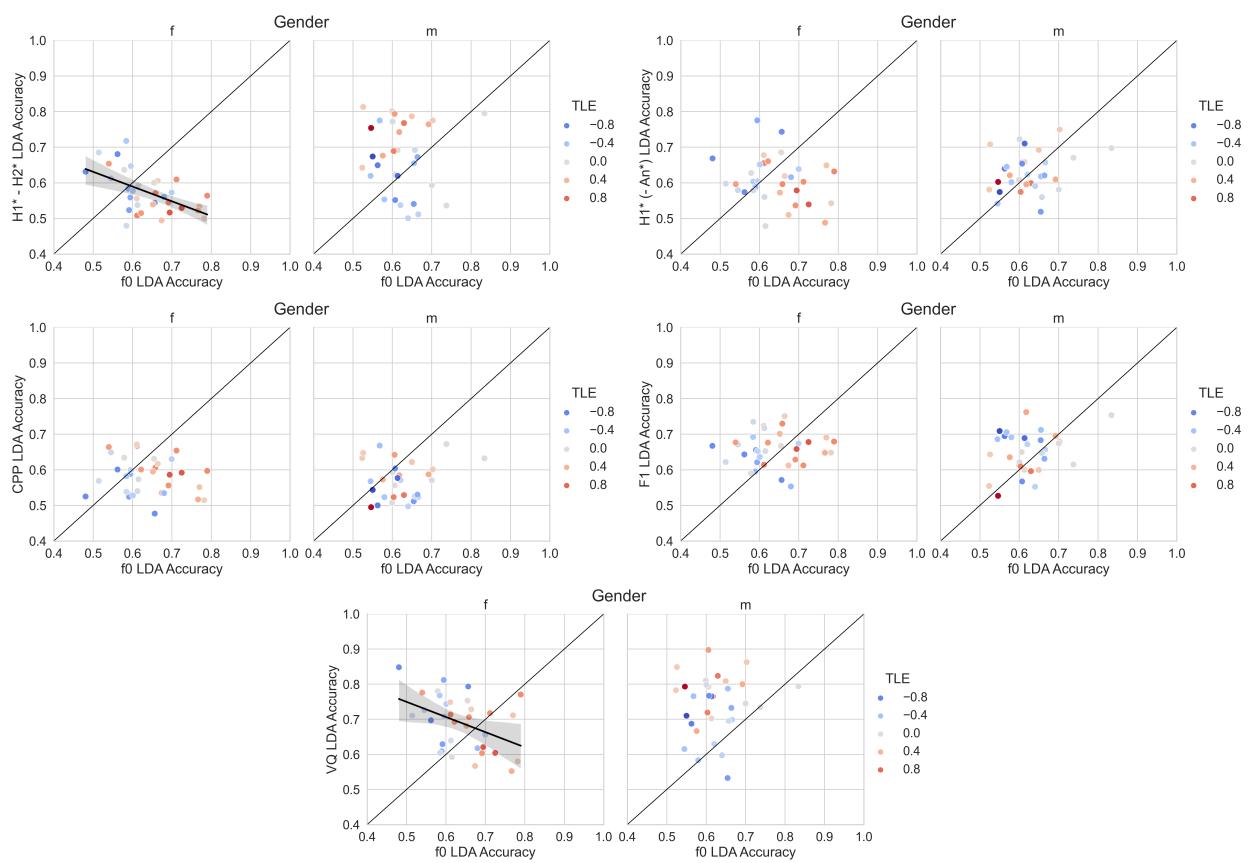


Figure 12: Correlation of LDA Accuracy of each acoustic measure to TLE

The individual results provide evidence supporting both hypotheses, but only for female speakers. Female speakers show f0 as an increasingly reliable cue over voice quality with greater usage of a tonal language. $H_1^* - H_2^*$ and VQ both show a tradeoff with f0. Male speakers, on the other hand, do not behave as hypothesized. While greater TLE does weaken F1 cue weights, it also increases $H_1^* - H_2^*$ weights, and $H_1^* - H_2^*$ becomes an increasingly reliable cue over f0 with greater TLE. Neither group shows any significant relationships with Time Away on the individual level.

4 Discussion

This production study provides a detailed look into the complicated relationship between the shifting of cue weights and social factors related to language usage. The diversity of language experience in the Kuy population is mirrored in the large variation in cue usage among different speakers and female and male speakers have starkly different patterns.

4.1 Tonal language experience and the register contrast

The results for female speakers show a clear relationship between increased tonal language usage and heavier f0 and CPP cue weighting alongside weakening of $H_1^* - H_2^*$ and $H_1^*(-A_n^*)$ differences from both the group results as well as in individual patterns. Furthermore, f0 also trades off with $H_1^* - H_2^*$ and voice quality in general in individuals. Despite the heavier weighting of CPP in speakers with greater tonal language experience, it is the most important cue for only one speaker. The evidence for a relationship between tonal language and f0 cue weighting for male speakers is visible on the group level, but not on the individual level. In Lau-Preechathammarach (2022), pitch halving in a number of modal voice tokens led to the unexpected finding of higher f0 in breathy voice than in modal voice in both female and male speakers with lower TLE and Time Away values. With these values corrected for, the unexpected finding of higher f0 in breathy voice in conservative speakers disappears, although these speakers still show the smallest f0 differences between the registers for both genders. Male speakers who use tonal languages more show larger f0 differences at the group level as well as longer persistence of differences over the course of the vowel, but show no clear importance for f0 at the individual level. The two relationships that do appear to hold on both the group and individual levels are the decreased weighting of F1 and unexpected increase in $H_1^* - H_2^*$ weighting with more tonal language usage.

One key point to be aware of in interpreting differences between the group and individual results is the fact that the LDA results are more informative about the *overall magnitude* of differences between the registers about the *duration* over which acoustic differences persist. The effect of both TLE and Time Away on f0 trajectories for male speakers is most visibly the persistence of differences over the duration of the vowel, rather than the magnitude. The incorporation of temporal information in the LDA analysis only indirectly, through the inclusion of acoustic measures from all 20 time bins, may thus obscure key differences, as contrasts are sensitive not only to magnitude, but also to temporal differences. A perception experiment with manipulation of both magnitude and contour of f0 differences would elucidate the extent to which speakers are sensitive to these factors in the register contrast.

Even with all the voice quality cues combined, the LDA still performs less accurately than for f0 for 14 speakers. Of these speakers, at the time of the study, two had recently graduated from college, three were teachers, one was a storeowner, and the rest took up various odd jobs. The remaining half were farmers (an unsurprising number, as 40 out of the 66 participants were farm-

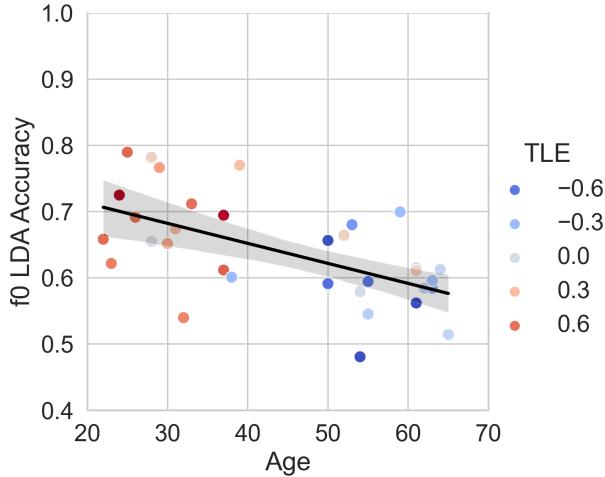


Figure 13: Correlation of age to f0 cue weights

ers). Teachers and graduated students are currently or recently immersed in the Thai education system and the speaker who takes up odd jobs regularly interacts with members of nearby communities, many of whom are not Kuy, but rather Lao, Khmer, and/or Thai. The overrepresentation of these jobs potentially provides some insight into why these speakers may have particularly high f0 cue weights in comparison to voice quality ones, but given the small numbers, this idea remains speculative.

4.2 Separating age effects from tonal language experience

Given the fact that age is one of the main factors in the TLE principal component, one might wonder whether the shift towards heavier f0 cue weighting in female speakers is merely a generational change, rather than due to language usage. Unfortunately, because age is strongly tied to language usage, with the younger generation using Thai more frequently and proficiently than the older generation, these factors are difficult to tease apart. However, we can inspect variation within age groups. In Figure 13, Age is plotted against f0 accuracy for female speakers, with points shaded for TLE. Unsurprisingly, there is a strong significant negative correlation between Age and TLE ($r = -.59, p < .001$); however, what is also noticeable is that in the 50 to 70 age group, most of the speakers above the regression line are lighter shades of blue than those below the line and there are even two who are shades of red. Meanwhile, within the 20 to 40 age group, the speaker with the lowest TLE (i.e. the one who is a shade of blue), has the second lowest f0 accuracy score (60.08%). The sample sizes are too small to claim that these patterns are necessarily meaningful, but the trend suggests that TLE may be responsible for heavier f0 cue weights *separately* from age. In order to tease these factors apart more, we would need to find more younger speakers with low TLE and more older speakers with high TLE.

4.3 Time away and the register contrast

Time spent away from home appears to have a small effect on male speakers at the group level, correlating with a modest increase in f0 and $H_1^* - H_2^*$ cue weights. At the individual level, however, no patterns are significant for either female or male speakers, but as mentioned before, this may be because of the lack of time course information for the cue. While TLE captures

participants' language usage at the time of the study, the Time Away variable was included in order to capture language usage over a participant's lifetime, as Kuy usage is assumedly much lower in comparison to Thai and potentially Lao usage while away from home. One possibility for the lack of a clear pattern for the effect of Time Away is that it may be too coarse a variable to be an actual proxy for language usage over time. While it is likely that people use less Kuy while living in other places, the extent may differ by individual. For example, it may be the case that many younger people living in other places still use Kuy daily, as smartphones have vastly improved the convenience for remaining in touch with those far away. One's occupation while away from home also influences one's social circles and subsequently one's language usage. Another possibility is that Time Away has little, if any, effect on cue weighting, particularly if the speaker's language usage does not change much, despite being away from the Kuy village. Ultimately, the effect of time spent away from home must be explored in finer detail through a more careful inquiry into the exact nature of people's language usage during the time they spend away from home.

4.4 Gender differences in register cues

The relationship between usage of tonal languages and f0 cue weights in production does not appear to bear out for male speakers. While the group results provide potential evidence aligning with the hypothesis, in that f0 differences persist longer for speakers who use tonal languages more or who have spent more time away from home, the individual results provide no evidence for such a relationship. One possible reason for the discrepancy between the two results is that the differences in the individual analysis may be masked by the lack of time as a factor in the LDA analysis, since the differences for male speakers appear to be in the *persistence* of f0 differences rather than in the magnitude. A point of note is that the results in Lau-Preechathammarach (2022) do show that male participants show a clear positive correlation between tonal language usage and f0 *perception* weights on the group level.

Where do these differences by gender come from? The key to this puzzle may partially derive from the differences in the histories of female versus male speakers. According to Hesse-Swain (2011, p. 44), migration of Isan people to larger cities as "cheap, unskilled labor" grew following World War II, although gender dynamics have changed over time: in the 1960s, rural migrants were mostly men without spouses or children, but by the 1990s, consisted of all ages and genders. Among the participants that I surveyed in this study, men generally reported traveling to other provinces in order to carry out manual labor, such as cutting sugarcane, while women would tend to be salespeople. This difference in occupation results in different social networks: men may have tighter social networks due to the isolated nature of manual labor while women may have looser social networks (more weak ties) due to interacting with various customers and other merchants. Differences in social network structure have been linked to differences in the diffusion of linguistic change (Bortoni-Ricardo, 1985; Milroy & Milroy, 1985; Eckert, 2000; Fox et al., 2011; Sharma & Dodsworth, 2020); in this instance, women would particularly be using much more Thai due to the various people with which they would come in contact. Thus, women may show increased f0 differences from using Thai in a variety of contexts due to of the nature of their social circles.

4.5 Conclusion

The key result of this study is that the usage of a tonal language has the potential to act as a catalyst for tonogenesis, contributing to the understanding of how language contact and bilingualism play a role in sound change through the sharing of cue usage. However, the implications are confounded by the fact that male speakers with greater Tonal Language Experience do

not show increased usage of f0, but surprisingly, do show increased usage of voice quality cues. This could mean that either the finding for female speakers is spurious (although note that Lau-Preechathammarach (2022) does demonstrate that male speakers with greater Tonal Language Experience show increased usage of f0 in perception) or that other social factors may be playing a role. The different social circles, largely due to occupation, of women and men, particularly among the older generation who migrated to work in other areas of Thailand, was discussed as potentially playing a role. To test whether this may be the case, future work could attempt to explore the role of social networks by controlling for both gender and social network, either through a detailed investigation of the number of strong and weak ties for each speaker, or through using occupation as a proxy.

The finding of a tradeoff of phonation cues for f0 cues for female speakers is compatible with previous studies by Sukgasame (2003), Sukkasame (2004), and Abramson et al. (2004), who find shifts towards usage of f0 as a cue in the register contrast in other Ku(a)y communities. They also mirror findings by Pratankiet (2001) and Sipipattanakun (2014) by demonstrating that usage of Kuy not only affects usage of Lao, but also vice versa. The shift in cue usage due to knowledge of another language aligns with previous literature on bilinguals' L1 and L2 cue usage. Given the sociolinguistic entanglement of the four languages in the area, however, the different languages that Kuy individuals use cannot easily be categorized into L1, L2, etc. While Kuy was a first language for all participants in this study, it is also the case that many of them acquired other languages simultaneously from a young age, due both to the national status of Thai and the common ethnolinguistic diversity of families and social circles. Although this study can not be cleanly classified as a study on L1 effects on L2 or vice versa, it does speak to the general diffusion of cues across languages within a bilingual speaker. With respect to the question of areal diffusion of tone, I do not take the strong view that Thai or Lao *induce* tone in Kuy, but rather align with Brunelle (2009) and Ratliff (2015) in suggesting that preexisting f0 differences in the register contrast may be *enhanced* through the shared cue usage, thus making Kuy more "tone-prone". This enhancement shifts the complex of register cue weights in Kuy, and while it does not necessitate the contrast to transform into a tonal one, the distancing of modal and breathy f0 distributions may cause listeners to be more likely to identify f0 as a meaningful cue, subsequently increasing the probability of tonogenesis occurring. While Kuy speakers have been in contact with Lao, Khmer, and Thai speakers and have been multilingual in these languages for a long time, it is the current social shifts that have pushed the tides of language usage towards greater usage of Thai in particular. The rich variation in the community offers insights into the mechanisms by which such transitioning behaviors of language usage translate into cue shifts, laying the groundwork for sound change.

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Conflicts of interest

The author has no conflicts of interest to declare.

Notes

¹Few studies have looked at F2 systematically (p.c. Marc Brunelle)

²Sources vary on the IPA notation used for the high central ($u \sim i$), high-mid central ($\text{y} \sim \text{e}$), and low-mid front ($\text{ɛ} \sim \text{æ}$) vowels. For consistency, I notate these vowels respectively as /u y ε/.

³There is no widely established orthography yet, although Kuy speakers adapt Thai orthography, with much variation, to spell out Kuy words when texting or using social media. One Kuy orthography that has been developed is an original script by Kuy community member Dr. Sanong Suksaweang, an introduction of which may be found at <https://www.youtube.com/watch?v=GUfa0x2tnAw>. Researchers at the Research Institute for Languages and Cultures of Asia (RILCA) at Mahidol University have also worked with Kuy speakers in Ban Khi Nak to develop a working Thai-script based orthography, which may be found at <http://www.langrevival.com/project/kuy-orthography>.

⁴Complementizer

⁵Values over 1 or less than -1 indicate heavy skewness, while values between -0.5 and 0.5 indicate relative symmetry.

⁶The conversion formula is below, where Hz_0 is the reference Hz value (thus set to 0 semitones) from which the number of semitones is calculated. 75 Hz is the reference value for this study.

$$\text{semitones} = 12 \times \log_2 \frac{Hz}{Hz_0}$$

⁷The 4-way interaction between Timepoints, Register, Gender, and Away on $H_1^* - H_2^*$ is significant only at Time 1 ($p < .05$) and the one between Timepoints, Register, TLE, and Away on F1 only at Time 3 ($p < .05$). Since these effects are significant only at one timepoint, they will not be discussed.

⁸p-value significance: * = $< .05$, ** = $< .01$, *** = $< .001$

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