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From Voice Quality to Tone: Multilingualism in Northeast Thailand and Shifting Cue Weights

Author
Lau-Preechathammarach, Raksit Tyler

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From Voice Quality to Tone:
Multilingualism in Northeast Thailand and Shifting Cue Weights

by

Raksit Tyler Lau-Preechathammarach

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Committee in charge:

Dr. Andrew Garrett, Co-chair
Dr. Susan Lin, Co-chair
Dr. Justin Davidson

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Abstract

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How do neighboring languages come to resemble one another, regardless of their genetic affinity? The literature is rife with examples of areas all over the world where languages have converged and share multiple features, but what are the exact mechanisms by which these large-scale effects come about? This dissertation integrates viewpoints from phonetics, phonology, historical linguistics, sociolinguistics, language contact, and multilingualism to investigate this question. Ultimately, the effects that we see from language contact are a form of language change involving influence from other languages. However, as languages cannot directly influence one another, the question cannot be answered without analyzing what individuals are actually doing in language contact situations. Naturally, these situations entail that they are speaking and listening to multiple languages, and so it is the production and perception of language that this dissertation will probe.

Previous work on language contact has acknowledged bilingualism as a prerequisite for contact-related changes that permeate beyond the lexicon and derives language contact effects as deriving from processes of imposition of one language's grammar onto another within bilinguals; however, much of this work tends to be restricted to theorizing these processes from the surface *outcomes* of language contact. On the other end, there is a wealth of experimental literature exploring how bilinguals use cues in their first and second languages; however, much of this work is focused on the question of what bilinguals do, without expanding to the broader context of how the results may have implications for understanding contact effects on language change. As such, this dissertation seeks to unify these two bodies of literature.

The sound change of interest is *tonogenesis*, the emergence of contrastive tone, which is well-known to arise from segmental contrasts through a combination of articulatory and perceptual factors involving co-occurring phonetic cues in phonological contrasts. The existence of

co-occurring cues in a phonological contrast is of particular interest from the language contact/multilingualism angle, as the informativity of a cue may be influenced by the informativity of that cue in another language spoken by the multilingual. As a case study, I examine the realization of phonological register in a quadrilingual Kuy community in Northeast Thailand as a case study. Members of this community speak two non-tonal languages, Kuy and Khmer, and two tonal ones, Lao and Thai. As pitch is a cue common to both register and tonal contrasts, I explore how Kuy speakers' usage of pitch aligns with their usage of these languages by carrying out a production and perception study and analyzing the results in the context of sociolinguistic data. I hypothesize that greater usage of tonal languages will correlate to greater usage of f0 (fundamental frequency) in the Kuy register contrast. I also discuss how these language patterns arise against the background of increasing pressures to use Standard Thai, due to a combination of changing schooling patterns, greater mobility between provinces, and an overall higher degree of centralization.

Chapter 1 provides the relevant sociolinguistic background and language contact situation of the quadrilingual situation in the Kuy community and review literature related to sound change, language contact, and multilingualism.

Chapter 2 explains the context in which I carried out linguistic fieldwork and the methods I used to process and analyze the sociolinguistic and phonetic data from the studies.

Chapter 3 describes the production experiment I carried out. Participants embedded target Kuy words differing minimally in register in a carrier sentence. The results show stark gender differences, with female speakers showing a positive correlation between usage of tonal languages and usage of f0 in production of the Kuy register contrast, and male speakers lacking any correlation. The relationship between usage of tonal languages and usage of voice quality was more complicated, including a mix of positive, negative, and null correlations.

Chapter 4 describes the perception experiment I carried out. Participants listened to perceptual stimuli of Kuy minimal pairs manipulated for f0 and voice quality and identified the register of each stimulus in a forced-choice task. The results show a positive correlation between usage of tonal languages and usage of f0 in perception of the Kuy register contrast for both female and male listeners. There was no relationship found between usage of tonal languages and usage of voice quality.

Chapter 5 explores the relationship between the production and perception results by examining the results in tandem in participants who partook in both studies. The results show a positive correlation between usage of tonal languages and usage of f0 overall and no significant relationship with usage of voice quality. This chapter discusses potential explanations for asymmetries in the findings with regards to gender and for differences in the production and perception results. I also analyze and discuss the usage of f0 in the register contrast in the context of three other ongoing sound changes that may also be linked to contact with Thai and Lao.

Finally, in Chapter 6, I summarize the findings and expand on the broader implications and propose that language contact effects can potentially be understood as the enhancement of preexisting features in a language due to the informativity of those features in another language. While this dissertation focuses on understanding how sound change can be shaped by language contact, changes at any level of language can be understood under the same framework. The results of these studies suggest that large-scale changes in social situations shift individual language patterns and trigger micro-level shifts in cue usage in a linguistic contrast. These shifts can bias languages to change in certain directions and set the stage for the macro-level language contact effects that we see over time.

To the people of Ban Khi Nak, and to all speakers of endangered and heritage languages

Our language is valid
Our language is beautiful
No matter how much it has changed

Contents

List of Figures

List of Tables

Acknowledgments

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Chapter 1

Background

It is well-known that linguistic features tend to be shared not only by genetically related languages, but also by languages that exist in close proximity to one another. When several languages coexist for long periods of time, they can give rise to a linguistic area, in which these languages come to share a constellation of features to the exclusion of languages outside the area. The convergence of these features is generally understood to come from an extended history of *language contact*. The literature is rife with explanations for features coming to exist in a language "because it is in contact with another language" or for two languages sharing structural features "because they are in contact". Such wording inadvertently evokes the image of two or more languages amorphously changing one another. Of course, languages are not physical beings that can actually directly affect each other. Language contact instead may be better understood as the *sum of interactions* between individuals who speak different languages.

If we accept language contact as deriving from individual interactions, then in order to understand how the effects deriving from language contact come to be, we must zoom in on the mechanisms that take place in these interactions. While lexical borrowings may occur with little to no knowledge of another language, changes beyond the lexicon that affect linguistic structure have been argued to require bilingualism. As such, it is vital to investigate the linguistic repertoires of bilinguals in order to derive the effects of language contact, and we might even extend our understanding of language contact to include not only interactions *between* different individuals, but also interactions *within* individuals who speak different languages. There is a wealth of experimental work on bilinguals' linguistic repertoires. While much of this work comes from the second language acquisition literature and focuses on exploring how bilinguals use their preexisting L1 knowledge when acquiring an L2 language, there is also work on effects in the opposite direction, looking at how L2 language exposure and usage affect L1 phonological categories.

Much of the work on contact-induced language change seeks to explain already completed changes; however, looking at changes in progress is also crucial to a better understanding of the extent to which contact actually plays a role in these changes. Exploring how bilinguals use language is one way of looking at language contact effects in progress, particularly when there is widespread bilingualism in a linguistic community. When language dynamics in a community shift, such that a language comes to be used less or more, we might expect the changing usage to affect linguistic repertoires on the individual level as well.

Linguistic variation in a multilingual community may be structured by individuals' language usage and experience, particularly in situations where language patterns shift because of societal change. If these individual changes reach a critical mass, they can set the stage for larger-scale contact effects that we see on a longer time scale. Because the literature on language contact and the literature on bilingualism have generally been treated separately, this dissertation aims to integrate these two strands of literature by examining individual-level multilingualism in the larger context of societal-level language contact and the overarching relationship with language change.

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. Register contrasts are characterized by a cluster of cues, including voice quality, vowel quality, fundamental frequency (f0), and amplitude. Speakers, however, differ in the extent to which each cue manifests in the contrast; the object of study is the relationship between the distribution of cues and language experience and usage patterns in the Kuy community of Tambon Tum.

Kuy populations in Thailand live in a historically quadrilingual society, but the continually increasing centralization of Thailand has pushed language usage to trend towards Kuy-Thai bilingualism. As standardization pressures lead Kuy speakers to increasingly shift to the national language, Thai, we might expect there to be changes involving cues that are shared between these languages, such as f0, 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 dissertation delves into differences in the interaction between language usage, social factors, and the acoustic correlates of the Kuy register distinction. The goal of these studies is to provide a close analysis of how we might understand the macro-effects of language contact on linguistic structure in the 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 show a shift in cue prominence in the register contrast that correlates with language experience, although the details are nuanced, with patterns diverging depending on gender and with different results for perception and production. 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 interpreted as language contact effects.

My intended audience for this dissertation is relatively diverse: the methods draw from laboratory phonology and sociolinguistic studies, while the theoretical questions asked are largely about sound change; as such, this thesis will be of interest to phoneticians, phonologists, sociolinguists, and historical linguists who study language change. Because the setting in which these studies take place is highly multilingual and lies at the crossroads of multiple language communities, I also hope that linguists who study bi-/multilingualism and those who study language contact will find value in this dissertation and will be inspired to find more common ground with and to draw perspectives from one another. The pressures and effects of language shift on an ancestral language will also be familiar patterns to linguists who study heritage and/or endangered languages. Finally, this dissertation will be relevant to linguists who research Austroasiatic languages and/or languages of Thailand and the greater Mainland Southeast Asian area, all three of which are understudied topics in the linguistic literature.

This chapter begins with a short note on the transcription of Thai/Kuy in this dissertation in §1.1, followed by a background of the phonology and sociolinguistic background and situation of Kuy and the other languages of the area in §1.2. §1.3 discusses the theoretical and experimental literature on cue weighting and its relationship with sound change. §1.4 lays out the literature on contact effects and on bilingualism to provide context on the close relationship. Finally, §1.5 summarizes how contemporary changes in Kuy society and identity may be reflected in changes in the language that have been noted by other scholars.

1.1 Notes on transcription

Thai romanization is not fully regularized—while the Royal Thai General System of Transcription (RTGS) is officially used in many cases, there is still some amount of inconsistency even in proper nouns. Furthermore, as vowel length, tone, and some vowel qualities are not distinguished, spelling can be often ambiguous. In this dissertation, I will adhere to the RTGS as closely as possible for proper nouns. However, because of the ambiguity, I will include Thai orthography and IPA when first introducing less common proper nouns, such as village names, that may not be easy to find through an online search, such that the reader is able to access information about them if needed.

1.2 Languages in contact in Southern Isan

Isan, the common name for Northeast Thailand, is a region well-defined geographically by the Khorat Plateau and culturally by the dominant presence of Lao culture and dialects. The area that will be focused on in these studies is the southern part of the region, occupied by four provinces: Buriram, Surin, Sisaket, and Ubon Ratchathani. The southern borders of these provinces form a natural border with Cambodia, defined by the Dângrêk Mountain Range, while the northern borders roughly follow the Mun River, except for Ubon Ratchathani, which is bisected by the river running through its capital. A map, with the Isan region outlined in white and the four provinces mentioned above each outlined in red, is provided in Figure 1.1. This region is primarily populated by three distinct ethnolinguistic groups: the Kuy, the Khmer, and the Lao. Each group speaks its own distinct language and is also minimally bilingual in Thai.

The sociolinguistic situation of the Kuy

The ethnolinguistic group that is the focus of this paper is the Kuy. Kuy กูย [ku:j] (ISO 639-3: kdt) 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 varieties known as Kuay กวย [kuaj] (which shares the same ISO 639-3 code) and Nyeu เญอ [ɲə:] [ISO 639-3: nyl]. These groups are also known by the exonym *Suay* ส่วย [suàj], derived from a system of paying tribute to the Thai

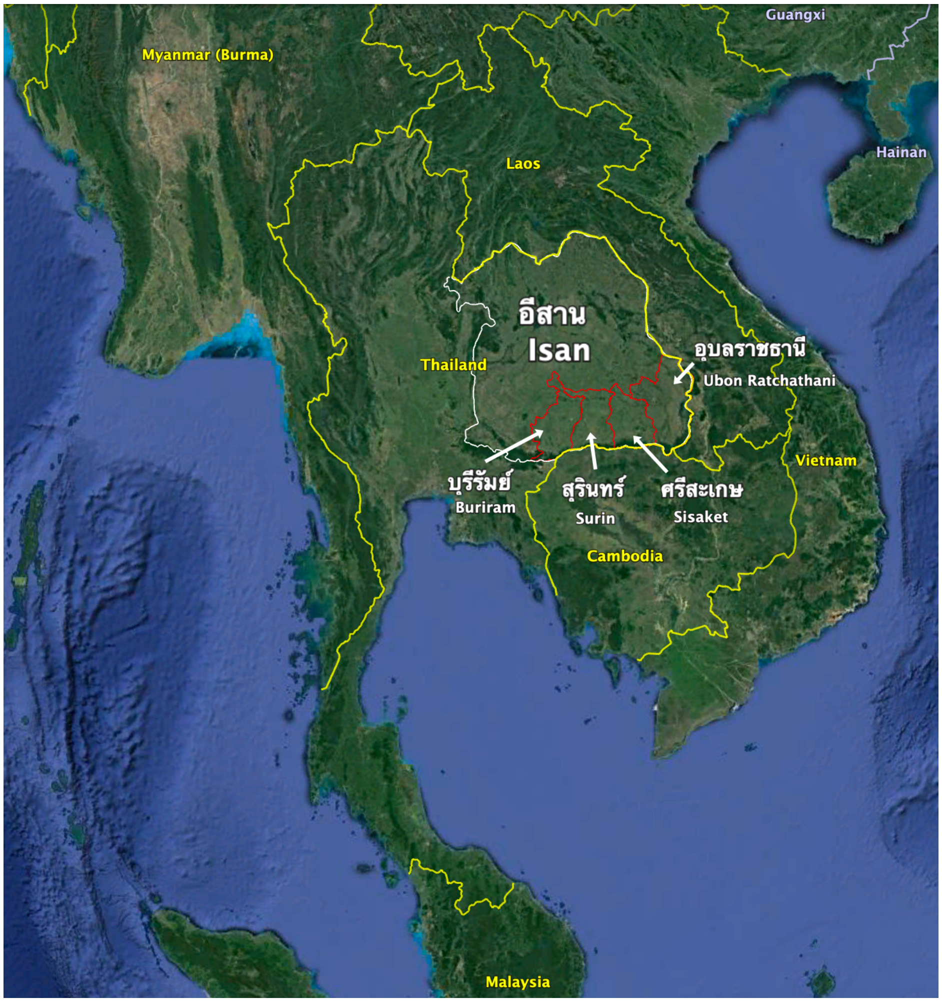


Figure 1.1: Map of Thailand

government known as ส่งส่วย [sòŋ suàj] 'to pay taxes'. In the era of King Rama III (1788–1851), this system was applied to populations in southern Isan and Laos, many of whom were Kuy. Taxes were required to be paid in the form of products from the forest. In the event of being unable to pay, people would be sent as labor instead. These individuals were called คนส่วย [kʰōn suàj] 'tax people', hence the name (Phumisak, 1976, 287, quoted in Sukgasame, 2003, 11). While the Kuy generally refer to themselves as *Suay* to outsiders, the term is considered derogatory by some members of the Kuy community. Given the multitude of varieties and names and the lack of an umbrella term, *Kuy* will be used in this paper both as the umbrella term as well as to refer to the specific variety I worked with, for consistency.

Various estimates of the number of Kuy speakers in Cambodia, Laos, and Thailand are provided in Table 1.1. The last count for each country is calculated from my extrapolations involving the most recent census data I could find: The 2008 General Population Census of Cambodia noted that of Cambodia's minority population of 383,273, 7.47% spoke Kuoy[1] (National Institute of Statistics, 2009, 30). The 2015 Laos census cites the total population of Laos as 6,492,228 and only includes counts for ethnic groups who made up at least 1% of the population: as the Kuy are not in this list, we can infer that there were no more than 64,922 ethnic Kuy in Laos in 2015 (Lao Statistics Bureau, 2015, 36–37). The 2010 Thai census counts 318,012 speakers of local/indigenous languages throughout the country—assuming this figure is accurate, the number of Kuy speakers would be less than this (National Statistical Office, 2015). Markowski (2005, 9) states that census data in Cambodia relies on ethnic identity rather than language and that some Kuy identify themselves as Khmer in censuses. The Thai and Lao censuses likely face the same issues.

Table 1.1: Estimates of Kuy population in different countries

Country	Approximate Population	Source
Cambodia	23,000	Lefebvre (2000)
	28,630	National Institute of Statistics (2009, 30)
Laos	50,000	Chazée (1999)
	< 64,922	Lao Statistics Bureau (2015)
Thailand	275,000	Smalley (1994, 368)
	400,000	Premsrirat (2006)
	< 318,012	National Statistical Office (2015)

Figure 1.2 shows the distribution of the Katuic languages from Diffloth (2011, 10). The red arrow that I have added points to the Kuy variety in the current study, which is spoken in Tambon Tum. I have added country names and borders (in thick black) to supplement Diffloth's map.

The Kuy are historically quadrilingual in Kuy, Khmer, Lao, and Thai. These four languages exist in a usage hierarchy in a classification devised by Smalley (1994):

1. **Standard Thai** [ISO 693-3: tha] sits at the top, being the *national language* taught in schools.

2. **Northeastern Thai** [ISO 693-3: tts], lies just below Standard Thai as one of the four *regional languages*: Central Thai, on which Standard Thai is based, Northeastern Thai, Northern Thai, and Southern Thai. Northeastern Thai encompasses 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". However, given the political boundary between Thailand and Laos, there are various sociolinguistic differences between the two. Other names for these varieties as spoken in Northeastern Thailand include "Isan", "Isan Thai", and "Isan Lao" (Akharawatthanakun, 1996, 1). The varieties spoken by the Kuy population in Thailand belong to the Southern Lao subgroup of Lao and are called /p^{h}sa: liạw/[2] in Kuy.

[1] This is the romanization of Kuay in Cambodia.

[2] /liạw/ assumedly historically derives from /lạ:w/ 'Lao' through diphthongization of breathy *ạ, given the notable lack of /ạ/ in the phoneme inventory.

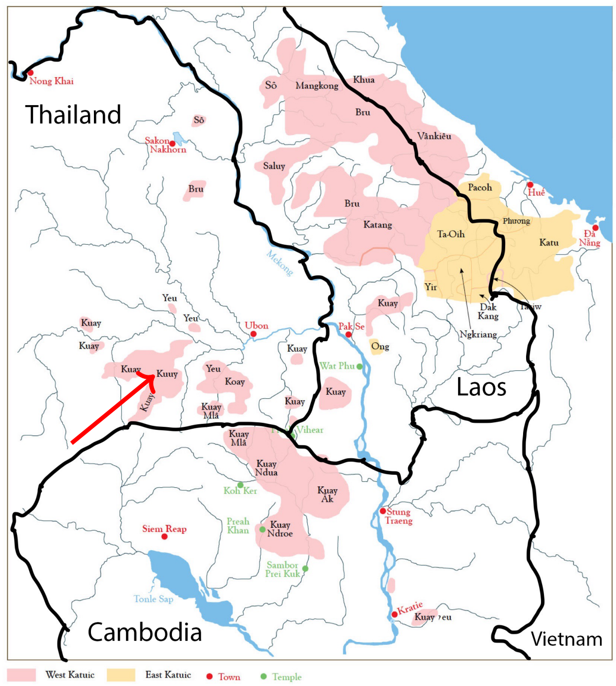


Figure 1.2: Distribution of Katuic languages, reproduced from Diffloth (2011, 10)

3. **Northern Khmer** [ISO 639-3: kxm], spoken along the Thailand-Cambodia border, has a sizable population of speakers and is codified as the national language just across the border, and so it comes next as a *marginal regional language*. It is also known as /khmer lɤ:/ 'high Khmer', /khmer sren/ 'Surin Khmer'[3], or in Thai as /kʰāmě:n tʰìn tʰāj/ 'Thai region Khmer'. Northern Khmer is a sister language to Standard Khmer [ISO 639-3: khm] and other varieties of Cambodia, collectively also called /khmer krɔ:m/ 'low Khmer'.[4] Kuy speakers refer to the language as /pʰsa: kʰme:r/[5].

4. **Kuy** [ISO 639-3: kdt] lacks national status in any country and so is considered a *marginal language*, lying at the bottom of this hierarchy.

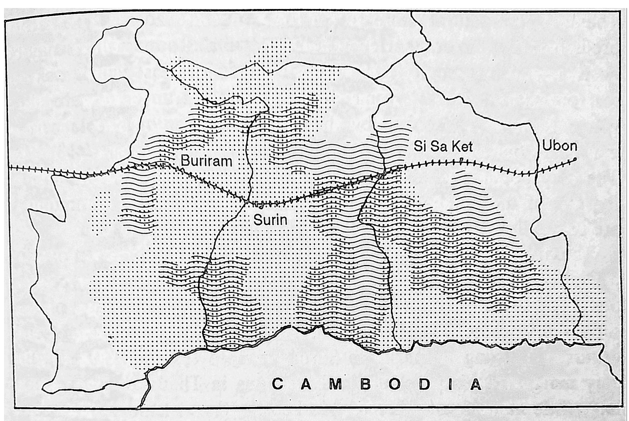
For brevity and clarity, the four languages in this study will be referred to as Kuy, Khmer, Lao, and Thai, while admitting that these terms homogenize and oversimplify both linguistic and social distinctions. Generally, an ethnolinguistic group can speak most, if not all, the languages in the area that are higher than their own language on Smalley's hierarchy, but not ones that are lower.

[3] Surin is the province in Thailand with the most Khmer speakers.

[4] The "high" and "low" distinction refers to the fact that Khmer speakers in Thailand live in higher altitudes than the Khmer in Cambodia.

[5] Or /pʰsa: kʰme:l/ for most speakers, who have merged coda /r/ with /l/.

Kuy history is marked by waves of assimilation to the Khmer and Lao populations of the area. From the 9th to the 15th centuries, the Khmer Empire was the dominating presence in the Kuy-inhabited region. This period overlaps with and was followed by the Lan Xang Kingdom (1353–1707), the predecessor of present-day Laos, during which there was a general absorption of various Austroasiatic populations (including the Khmer). Seidenfaden (1952) describes changing social dynamics leading to shrinking of the Kuy-speaking region, despite a growth in the Kuy population itself (Yantreesingh, 1980, 3; Smalley, 1994, 149–151). Figure 1.3 shows that by 1964, the Kuy-speaking area was both smaller than and also heavily overlapping with the Khmer-speaking area. Despite these facts, Kuy remains one of the most populous minority languages of Thailand, making up approximately 0.5% of Thailand's population at the time of Smalley's study (Smalley 1994, 149–151). With regards to recent language dynamics, Sukgasame (2003) points out that Thai is used in the classroom and in government offices while Premsrirat (2006) reports that 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. The reader may also refer to Phromthong (1996) and Tomioka (2019) for further work on Kuy language usage and language attitudes.



Map 9.3. Distribution of Kuy in relation to Northern Khmer. Kuy is shown by wavy shading. Overlap in shading shows areas where communities speaking the respective languages are intermingled.

Figure 1.3: Distribution of Kuy (wavy) and Northern Khmer (dots) in 1964 (Smalley, 1994, 149)

The current study looks at the variety of Kuy spoken in Tambon Tum ตำบลตูม [tāmbōn tū:m], a subdistrict of Prang Ku, a district of the province of Sisaket. In this subdistrict, there are three villages that are primarily Kuy speaking: Ban Khi Nak บ้านขี้นาค [bâ:n khî: nâ:k], Ban Rong Ra บ้านรงระ [bâ:n rōŋ ráʔ], and Ban Khi Nak Noi บ้านขี้นาคน้อย [bâ:n khî: nâ:k nɔ́:j]. All the participants in this study, except for two, were from these villages. Of the remaining two, one was from Ban Phlong บ้านพลือง [bâ:n pʰlɔŋ], a Khmer-majority village also in Tambon Tum, and one from Ban Huai Khong บ้านห้วยฆ้อง [bâ:n huâj khɔ́:ŋ], a Kuy-majority village in the nearby

Tambon Phimai ตำบลพิมาย [tāmbōn pʰíma:j]. According to Kuy speakers in Tambon Tum, these villages speak the same variety of Kuy.[6]

Demographic data looking at the progression of language shift may be seen in Tables 1.2 and 1.3. These data are from 100 speakers who participated in the production experiment, perception experiment, or both, in 2018 and 2019; note that those who participated in both experiments are counted only once.[7] The results are split by generation. Table 1.2 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 3 individuals who are only bilingual in Kuy and Thai. Table 1.3 shows self-assessment of speaking ability in each language as compared to Kuy. The most notable pattern is the generational shift from the majority of speakers rating their Thai ability as less than their Kuy ability (28/51) to the majority of speakers rating their ability equally in the two languages (28/49). 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 1.2: Lao and Khmer speaking ability (based on author's survey data)

Age	Neither	Khmer only	Lao only	Both	Total
>45	0	0	4	47	51
≤45	3	2	12	32	49

Table 1.3: Speaking ability compared to Kuy (based on author's survey data)

	Thai			Khmer			Lao		
Age	less	same	more	less	same	more	less	same	more
>45	28	21	2	42	8	1	38	13	0
≤45	11	28	10	44	4	1	38	7	4

The increasing shift to Thai in recent times is not unique to the Kuy, but is prevalent throughout Thailand, as a result of continued efforts to centralize the country. Three salient changes that have occurred over the past several decades are longer schooling, an increase in interregional travel, and greater consumption of central Thai media. The influence of schooling is particularly palpable. In the past, education in smaller villages in Thailand was traditionally centered

[6]For reference, the Kuy spoken in the bordering Tambon Saway ตำบลสวาย [tāmbōn sāwǎ:j] is characterized as a different variety, called [ku:j mlɑ:] after the word for 'what' in that variety of Kuy ('what' in Tambon Tum Kuy is /m̩pṳa/).

[7]This data includes participants whose results were not included in the experiment analyses.

in temples and revolved around understanding of the natural and supernatural rooted in Buddhism (Hanks Jr., 1958). Mandatory primary schooling was introduced in 1921 and schools have played a central role in the development of a national and unified Thai identity through emphasis of loyalty to three symbols—the King, the nation, and Buddhism (Smalley, 1994, 323, McCargo and Hongladarom, 2004)—and through the enforcement of Standard Thai in schools beginning in the reign of King Vajiravudh (1910–1924) (Suraratdecha, 2014, 240). As recently as 1994, schools in Isan spent much more time teaching Standard Thai than required by the nation (Keyes, 1966, 164–166). In Isan, teachers would teach younger grades using some Lao, phasing in Standard Thai gradually (Smalley, 1994, 95). This is likely due to the large population of Lao speakers, who made up approximately 23% of the population of Thailand in 1994 (Smalley, 1994, 368).[8] As a result, younger generations are becoming increasingly fluent in Standard Thai and mobile, moving to larger cities for job opportunities. 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 (Hesse-Swain, 2011, 44).

Ban Khi Nak School is the school that was attended by almost all participants in this sample. The timeline of its founding and expansion is shown in Table 1.4. 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. 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 are sometimes not even aware of the existence of the Kuy as a separate ethnolinguistic group.

Table 1.4: Ban Khi Nak School timeline (EMIS 2013, p.c. Sidawun Chaiyapha)

Year	Event
1939	School established (up to 4th grade)
1972	Expanded to 6th grade
1998	Expanded to 9th grade

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

[8] This figure is of course outdated now, but unfortunately, the category 'Lao' in the Thai census does not refer to citizens of Thailand who speak Lao, but rather, immigrants from Laos. As such, census data heavily underestimates the number of Lao speakers. The last national census was in 2010, when the percentage of "non-Thai" people (i.e. Lao, Burmese, Khmer, etc.) living in Isan was counted as 0.9% of the population of Isan (National Statistical Office, 2015), a number that would comprise less than 1% of Thailand's population (the report for the whole nation lumps together "Lao, Khmer, and Chinese" as 1% of the population). The number of Lao speakers in the nation was counted as 569,330, approximately 1.6% of Thailand's population (National Statistical Office, 2010). Comparing these figures to Smalley (1994), it appears that the number of Lao speakers is heavily underestimated in the census, likely because of the government's attempt at homogenization.

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 convenient and mainstream. The data in Table 1.5 is drawn from the same population as in Tables 1.2 and 1.3 and shows generational differences in the time that people have spent away from home. 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. This data mirrors the discussion by Hesse-Swain (2011, 44) about a shift in the gender balance of Isan migrants in recent times.

Table 1.5: Time spent away (100 speakers, data from current study)

Age	Has not spent time away		Has spent time away	
	F	M	F	M
>45	16	10	14	19
≤45	4	3	25	26

As a result of the younger generation spending more time in school and in other parts of Thailand, they use much more Thai and many consider themselves to be equally bilingual in Kuy and Thai, a finding mirrored in Siebenhütter (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 and Fennig, 2017) and as "severely endangered" by UNESCO (Moseley, 2010).

Phonology of Kuy and the surrounding languages

Segmental phonology of Kuy

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 of different Kuy, Kuay, and Nyeu varieties.

The consonants and vowels of Kuy as laid out by Phimjun (2004) may be found in Tables

1.6 and 1.7.[9] Phimjun's inventory is taken as it is based off data elicited in Tambon Ku ตำบลกู่ [tāmbōn kù:], the subdistrict bordering Tambon Tum to the south, where a closely related variety to Kuy in the current study is spoken.

Table 1.6: Consonants of Kuy (Phimjun, 2004, 24–25)

	Labial	Alveolar	Palatal	Velar	Glottal
Stop	p pʰ b	t tʰ d	c cʰ	k kʰ	ʔ
Nasal	m	n	ɲ	ŋ	
Fricative		s			h
Trill		r			
Lateral		l			
Glide	w[10]		j		

All the consonants in Table 1.6 also appear in coda position except for /s/ and aspirated and voiced stops. Coda /r/ has merged with coda /l/ for most speakers (for example, /pi:r/ → [pi:l] 'flower'). Another ongoing change is the merger of the onset cluster /tr/ with /kr/ (for example, /traj/ → [kraj] 'yes').

Table 1.7: Vowels of Kuy (Phimjun, 2004, 27)

	Front	Central(/Back Unrounded)	Back (Rounded)
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:

Table 1.8: Kuy/Kuay diphthong correspondence (Phimjun, 2004, 29)

Kuy	Kuay
u:	ua
ua	ɑ
ia̤	a:/a̤:[11]
i:	ia

[9]Sources vary on the IPA notation used for the high central (ɯ ∼ ɨ), high-mid central (ɤ ∼ ə), and low-mid front (ɛ ∼ æ) vowels. For consistency, I notate these vowels respectively as /ɯ ɤ ɛ/.

[10]/w/ is labiovelar and may better be characterized as the labiodental glide /ʋ/, as there is a labiodental gesture for a number of speakers in various contexts.

As can be seen in Table 1.7, Kuy has a rich vowel system like many other Austroasiatic languages. A length distinction exists for every vowel. Three diphthongs exist in Kuy: /ia ɯa ua/ (Phimjun, 2004, 29). The sound correspondences between Kuy and Kuay can be seen in Table 1.8. Diphthongs are a shibboleth for different Kuy varieties, as is apparent even from the difference in names of the Kuy and Kuay dialects.

Syllable structure of Kuy

Kuy monomorphemic words are maximally of the shape C(V/N̩).CRVC, in which C stands for a consonant, N̩ 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 phonetically ranges between nothing and a schwa or a syllabic nasal homorganic with the onset of the second syllable, and (3) there is no coda. This word shape with an unstressed and restricted first syllable ("minor syllable") is common in Austroasiatic and is termed *sesquisyllabic*, meaning "syllable and a half" (Henderson, 1952; Matisoff, 1973).[12]. The presence of the syllabic nasal shows age-graded variation in Tambon Tum, such that it is often dropped by younger speakers but rarely by older ones. In some speakers, the nasal is heavily reduced and may potentially be prenasalization rather than a syllabic nasal (see Ratliff (2015b) for a discussion on prenasalization/syllabic nasals in Mainland Southeast Asia and their phonological status). Thus, for older speakers [ⁿte:] 'to say' and [te̤:] 'no' do not form a minimal pair, as they differ both in the initial consonant and in the vowel quality, but for younger speakers it is a minimal pair: [te:] vs. [te̤:]. If there is a sesquisyllable with a nasal, the nasal is dropped. For example, many younger speakers pronounce the word for 'diligent' as [ctrʌ̤ŋ].[13]

Register in Kuy

Kuy has a two-way register contrast between *modal* and *breathy* voice, a common feature of Austroasiatic languages (Jenny and Sidwell, 2014, 53). This contrast is a subtype of a *high register* vs. *low register* contrast, a more general term that corresponds to a contrast between a register with higher pitch and more modal (or even creaky) phonation and a register with lower pitch and more breathy phonation (Pittman, 1985). The current study will refer to these categories as modal voice and breathy 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. One example gap is the lack of

[11] 3 out of 4 of Phimjun's examples show an /ia̤/ ∼ /a̤:/ correspondence and it is likely that the one /ia̤/ ∼ /a:/ example (/ni̤a̤ŋ/ ∼ /na:ŋ/ "ตัวไหม (silkworm)") is a typo, particularly given the voice quality mismatch.

[12] Pittayaporn (2015) shows that sesquisyllabicity is heterogeneous across languages and also argues that it is a syllabification strategy to avoid typologically marked onset clusters. In his typology, Kuy is a B2-type language, meaning that sesquisyllabicity is not contrastive with monosyllabicity and that complex onsets are permissible, but must obey Clements' 1990 version of the sonority hierarchy.

[13] Some speakers drop the first consonant instead, yielding [ⁿtrʌ̤ŋ]

breathy /a̤:/.[14] The distinction between voiceless unaspirated and aspirated stops is neutralized before breathy vowels (Sriwises, 1978, ฑ)[15], a common feature of Katuic (Huffman, 1976; Diffloth, 1982; Gehrmann and Kirby, 2019). This restriction appears to also hold in Gujarati and may be a common tendency grounded in the difficulty of perceiving the difference between modal and breathy vowels following aspirated stops, which share acoustic cues with breathy vowels (Silverman, 1995, 100). The modal vs. breathy distinction is exemplified by the minimal pair *lu:* 'to howl' vs. *lṳ:* 'thigh'. Sriwises (1978, vii) and Sukgasame (1993, 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.

Several varieties of Kuy appear to be increasingly using pitch to distinguish the registers. L. Thongkum (1989, 14) shows that in one dialect of Kuy in Surin province, breathy voice is correlated with lower pitch and amplitude than modal voice. Abramson et al. (2004) show through a perceptual study that the use of phonation has virtually disappeared from the register contrast and that it is pitch that is the salient cue in a variety spoken in Samrong, Surin province. In a series of papers, Preecha Sukgasame (romanized alternatively also as Sukkasame or Sukkasem) described the pitch patterns of the two registers and their interactions with syllable shape in a number of Kuy and Kuay dialects. In Sukgasame (1993), he described the register pitch patterns as being predictable based on the coda, in the pattern shown in Table 1.9 (note that Sukgasame does not describe what happens if the coda is /h/).

Table 1.9: Kuy registers and pitch patterns by syllable type

	Modal	Breathy
Ends in nasal or ∅	high falling	low falling
Ends in stop	high level	low rising

Sukgasame (2003) carried out an apparent time study on four Kuy ∼ Kuay varieties—one in Laos and three in Surin province in Thailand—and found that the breathy vs. clear distinction in younger speakers is giving way to a vowel quality distinction in the Lao variety, but to a pitch distinction in the Thai varieties. Following up on details of this pitch distinction, Sukkasame (2004) looks at two varieties of Kuy (one in Ban Uthumphon บ้านอุทุมพร [bâ:n ùt^{h}ūmp^{h}ɔ̄:n] in

[14] The sound correspondences in Table 1.8 make it apparent that the gap is probably due to an *a̤: > ia̤ change, such that Kuay preserves the original long breathy /a̤:/. Diphthongization often happens with low breathy vowels due to lowered F1 and a long transition from the breathy portion of the vowel into the modal portion. As further evidence of this change, words borrowed from Thai that have /a:/ following historically voiced consonants appear with [ia̤]. In Kuy, voiced consonants triggered breathy voice on following vowels (and if they were stops, they devoiced) (Gehrmann, 2016). For example, Thai *ra:ga:* (modern Thai: *rā:k^{h}ā:*) > Kuy *rkia̤* 'price', suggesting that the vowel was originally borrowed as breathy *a̤: and later diphthongized to [ia̤].

[15] Sriwises (1978) numbers pages before page 1 with letters of the Thai alphabet. ฑ is the 11th letter of the alphabet so this would essentially be page xi in English texts.

Sisaket and one in Ban Samrong บ้านสำรอง [bâ:n sămrɔ̄:ŋ] in Surin) and notes that the final glottals /h ʔ/ and the modal-breathy distinction (especially in Ban Uthumphon) are being lost in everyday speech and being replaced by pitch contours, yielding 6 pitch patterns that he surmises will take full hold in the future. Sukgasame attributes these changes to contact with Lao, noting other phonological changes that have made the Kuy phonological system closer to that of Lao and also noting that the pitch patterns match the 6 tonal contours of Lao well. The 3 tonal contours that derive from modal voice are described as starting high and the 3 that are from breathy voice are described as starting low.

Thus, it appears that some dialects of Kuy (and Kuay) may be shifting towards a register system in which pitch is more prominent. The variety spoken in Tambon Tum still has salient final glottals, but the phonation distinction is auditorily not as noticeable in many younger speakers as it is in older speakers. Insight can be gained into speakers' intuitions on the distinction as well via the use of Thai orthography in "folk transcription" (Hinton, 1991) of the modal-breathy distinction. Every voiceless aspirated stop in Thai can be written in at least two ways, historically deriving from a voiced-voiceless distinction. These two series are known as *high consonants* ($<$ voiceless aspirates) and *low consonants* ($<$ voiced).[16] In modern Standard Thai, if there is no tone mark, the vowel following a low consonant carries a mid-tone whereas the vowel following a high consonant carries a low-rising tone. If asked to spell a Kuy word in Thai orthography[17], Kuy speakers opt to use low consonants for aspirated stops before modal vowels and high consonants for stops before breathy vowels. *Middle consonants* are used to write voiceless unaspirated stops in Thai and are used for voiceless unaspirated stops before modal vowels in Kuy. These correspondences are schematized in Table 1.10 with a minimal triplet.

Table 1.10: The realization of Kuy voice quality in Thai orthography

Letter	Class	Old Thai	Modern Thai	Kuy word with letter	Gloss
ท+V	Low	d+V	t^h+mid tone V	t^he:	jar
ถ+V	High	t^h+V	t^h+low rising tone V	tḛ:	no
ต+V	Middle	t+V	t+mid tone V	te:	to say (newer pronunciation)

Sriwises (1978, ซ) states his own native speaker intuition about the consonants preceding breathy vowels being more similar to Thai aspirated consonants and also cites results from a

[16] Orthographic consonants representing aspirated stops beyond this binary distinction are used in words that preserve their Sanskrit/Pali spelling or are the result of a separate sound change.

[17] There 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 ดร. สนอง สุขแสวง, 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) สถาบันวิจัยภาษาและวัฒนธรรมเอเชีย 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 https://langrevival.mahidol.ac.th/project/kuy-orthography/.

perception test carried out with four speakers of Mon-Khmer languages in which they wrote 90% of breathy words played to them with high consonants. During my own fieldwork, speakers who did not have knowledge of the Mahidol orthography would spell words with breathy vowels with high consonants. This shared intuition along with Sriwises' results suggests that there is a crosslinguistic perception of equivalence between breathy vowels and the Standard Thai rising tone. Speakers also opt not to use orthography that would mark breathy vowels as a level low tone, suggesting a rising pitch contour for breathy vowels.

Other languages

The phonological details for Thai, Lao, and Khmer will be restricted to facts relevant to this study. Standard Thai has 5 tones: mid, low, (high-)falling, high(-rising), and (low-)rising, along with a sixth high tone posited for emphatic reduplication (Abramson, 1962; Tingsabadh and Deeprasert, 1997; Iwasaki and 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 5 or 6 tones—the Sisaket variety has 5 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, 109). Like Kuy, Northern Khmer is also not tonal and has a large vowel inventory, but unlike Kuy, it does not have a register distinction.[18] While most native words in both Thai and Lao are monosyllabic, many sesquisyllabic loanwords have entered the language through Khmer and polysyllabic ones through Sanskrit, Pali, and English (as well as French in the case of Lao). Khmer, on the other hand, shares the typical Austroasiatic syllabic structure with Kuy, having many sesquisyllabic and monosyllabic words. It also has polysyllabic loanwords from Sanskrit, Pali, English, and French.

Because pitch is a correlate of register, it is possible that the prominence of pitch in the Thai and Lao tonal contrast could influence the prominence of pitch in the Kuy register contrast due to the shared usage of cues. The largely monosyllabic nature of Thai and Lao may similarly push Kuy in the direction of monosyllabicity, which may indirectly increase the prominence of pitch, through a tradeoff in functional load between phonological segments and suprasegments. §5.3 will delve into greater detail on the relationship between syllable structure and tone.

1.3 Cue weighting and sound change

As discussed at the end of §1.2, previous literature has reported increased usage of pitch in the register contrast in some Kuy varieties. Before exploring social factors that may play a role in this ongoing change, it is important to understand the components of a contrast and how a contrast may change over time. The starting point for this discussion will be the multidimensionality of

[18]Western Khmer is the only Khmeric language that preserves register (Thongkum, 1988; Wayland and Jongman, 2003).

laryngeal contrasts, followed by a review of the processes of registrogenesis and tonogenesis, and finally a literature review of the role of cue weighting in phonologization.

The multidimensionality of laryngeal contrasts

Laryngeal contrasts are well-known for being multidimensional in nature. Perhaps the most well-known laryngeal contrast is that of voicing. While voicing contrasts were long understood to be cued by *voice onset time* (VOT) (Lisker and Abramson, 1964), it is now well-known that VOT differences occur concurrently with other cues, such as f0 and F1 transition differences, in many languages (House and Fairbanks, 1953; Hombert et al., 1979; Lisker, 1986; Dmitrieva et al., 2015; Kirby and Ladd, 2016; Sonderegger, 2021). Experiments have also shown that listeners reliably use these cues in perceiving voicing contrasts, particularly when VOT is ambiguous (Whalen et al., 1992).

One 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, 151; Gregerson, 1976; Huffman, 1976; Ferlus, 1979; Edmondson and 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 and Stevens, 1971; Ladefoged, 1973; Laver, 1980; Maddieson and Ladefoged, 1985; Gordon and Ladefoged, 2001; Gobl and Ní Chasaide, 2013). These pairs are often collectively referred to as "high" and "low" register. Table 1.11, adapted from Brunelle et al. (2020) and added to, summarizes crosslinguistic cues for register from various studies. Note that languages differ in which cues are reliable correlates of their register contrasts (Bickley, 1982; Thongkum, 1988; Andruski and Ratliff, 2000; Blankenship, 2002; Miller, 2007; DiCanio, 2009; Keating et al., 2011; Kuang, 2011a,b; Esposito, 2012; Esposito and Khan, 2012; Pan et al., 2011; Garellek, 2012).

Table 1.11: 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[19]	More peripheral?	More centralized?
VOT	Shorter	Longer
Vowel duration	Shorter	Longer

The multidimensionality of these laryngeal contrasts has been identified as a source of changes, such as the development of *tone*, a contrast in which pitch plays a prominent role and our other contrast of interest in this study.

Registrogenesis and tonogenesis

The concurrence of multiple systematic differences in voicing and register contrasts is a source for change over time. Diachronic data provides examples of the change from voicing contrasts to register, voicing contrasts to tone, and register contrasts to tone. The emergence of register is known as *registrogenesis*, whereas the emergence of tone is termed *tonogenesis*. Because of formant differences between vowels with the same vowel quality but different voice qualities, register contrasts may also lead a single vowel quality to split into two, in a process called *restructuring*. The shift from a voicing contrast to a modal-breathy phonation contrast has been proposed to begin with a transition to a lax-tense contrast, leading to redundant cues in the following vowel being breathy for slack voice and modal for tense voice (Wayland and Jongman, 2002). From a breathy-modal contrast, a low-high tonal contrast can then develop.

A language that has undergone tonogenesis from a previous modal-breathy contrast is Punjabi, in which historically breathy voiced consonants merged with voiceless unaspirated stops but the contrast was preserved by the maintenance of a low tone on the following vowel (Gill and Gleason, 1972; Haudricourt, 1972). Breathy voiced consonants are also shown to induce low tone on the following vowel in various languages, including Thakali (Hari, 1970), Ndebele, Zulu (Ladefoged, 1971, 14), and Hindi (Kagaya and Hirose, 1975). Hari states that in Thakali, breathiness is only audible in overdistinct speech and that it is the pitch and lax voice that is salient, as well as visible lowering of the Adam's apple (Hari, 1970, 129). This suggests that larynx lowering is the physiological mechanism that may be employed in lowering f0 in this language.

The Austroasiatic languages are well-represented by languages that lie on the spectrum from having no registral difference and preserving the voiced series from Proto-Austroasiatic (such as Loven and Stieng) to ones with complex tonal systems (such as the Viet-Muong languages) and with various languages that lie in between with register contrasts and/or simple tone systems (such as Mon and Chong). Restructuring is also represented in Kuy and Khmer (Huffman, 1976; Gehrmann, 2016).

Both registrogenesis and tonogenesis are subtypes of a more general process termed *transphonologization* (Haudricourt, 1965; Hyman, 2013), in which "secondary cues" in a phonological contrast come to replace the "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

[19] Few studies have looked at F2 systematically (p.c. Marc Brunelle)

the contrast has a high functional load (Baese-Berk and Goldrick, 2009; Wedel et al., 2013; Garrett, 2015).

Shifting cue weights and phonologization

The cues that lay the seeds for tonogenetic, registrogenic, or vowel quality changes come from the interpretation of acoustic cues that occur as a result of articulatory mechanisms employed in consonantal contrasts. The slackening of the vocal folds occurs in both voicing and breathy phonation. Slack vocal folds have less tension and greater mass per length, leading to slower vibration and subsequent lowering of f0. Laryngeal lowering can also be employed to maintain voicing and breathy phonation through increased subglottal pressure and, subsequently, airflow. The laryngeal lowering also has the effect of lowering f0. Laver (1980) and Edmondson and Esling (2006) may be referred to for more detail about laryngeal mechanisms in phonation.

Diphthongization and vowel quality changes also derive, indirectly, from the slackening of the vocal folds. Delattre et al. (1955) show that the acoustic loci for F1 in the voiced stops /b d g/ are all lower than vowel F1 values, and thus the formant transition for F1 into the following vowel is always in an upward direction. Breathy (and lax) voice also lowers F1, although there are cases in which breathiness is maintained only throughout part of the vowel (see discussions of the timecourse of phonation in Khan and Esposito (2011); Esposito and Khan (2012) for Gujarati and White Hmong and Silverman (1995, 120–121) for Mazatec, Chinantec, and Trique). Breathiness and slack voice both lead to a longer formant transition from the consonant into the vowel, due to a delayed release of the consonant. As central and low back vowels (such as /a/ and /ɔ/) have high F1 and low F2 values, the long transition from the low F1 can trigger the percept of a diphthong on these vowels (Wayland and Jongman, 2002). This fact explains why languages that have restructured a register distinction to a vowel quality one tend to show diphthongization in low central and back breathy vowels.

At the point where consonants are on the verge of devoicing, they are in danger of merging with voiceless stops. While merger is a potential outcome, it is also possible that merger is avoided. The term *functional load* refers to the relative informativity of a feature in keeping utterances apart (King, 1967). In the context of phonology, functional load is positively correlated with how many minimal pairs a phonological feature distinguishes. When functional load is high, there is a greater tendency for merger to be avoided, as to prevent too much ambiguity in the language (Priva, 2012; Bouchard-Côté et al., 2013; Wedel et al., 2013; Babinski and Bowern, 2018; Ceolin, 2020). One way to prevent merger is through the enhancement of cues on the vowel, which can in this case be voice quality, tone, or vowel quality. This process in which the contrast becomes transferred from the consonant to the vowel is an example of transphonologization. The consonant merger that occurs in the transphonologization differs by language: for example, Proto-Tai voiced stops merged with voiceless aspirated stops in some languages but unaspirated ones in others (Pittayaporn, 2009).

To schematize transphonologization, we can visualize a theoretical sample of words in a language that differ only in the voicing of the initial consonant. For each word, we plot the VOT of the initial consonant along the x-axis and the average f0 of the vowel along the y-axis, yielding

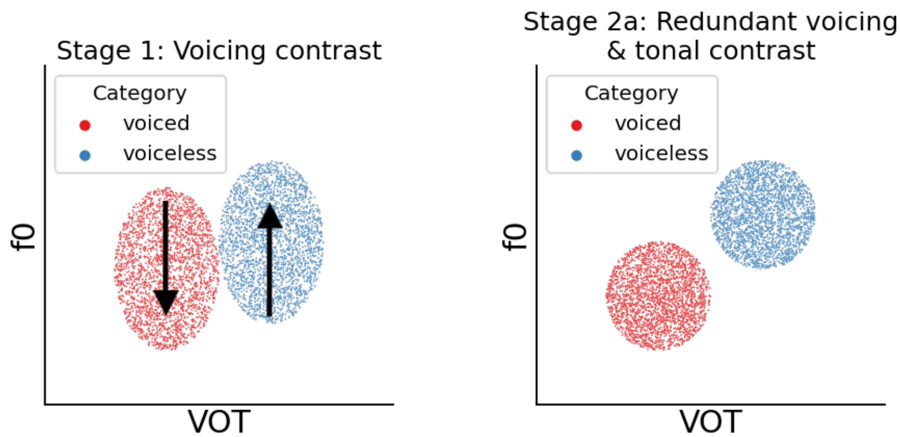


Figure 1.4: Enhancement of f0 differences yields redundant voicing and pitch contrast

two distributions resembling the left graph of Figure 1.4. As voicing is contrastive, the voiceless tokens have greater VOT values than the voiced ones.[20] While voiceless tokens show a higher f0 on average than voiced ones, there is much overlap between the distributions along the f0 dimension. The systematicity of greater f0 can lead to the identification of f0 as a significant cue and, subsequently, enhanced f0 differences (indicated by the arrows in the left graph of Figure 1.4). This process can lead the distributions to become more distinct along the f0 dimension, as in the right graph of Figure 1.4, in which the contrast would be defined not only by voicing, but also by pitch.

Alternatively, the voicing contrast may wane in speakers and could result in a near-merger and the distributions seen in the right graph of Figure 1.5. In this case, the categories are weakly distinguished along both the VOT and f0 dimensions. Merger is a possible outcome, but an alternate outcome is for merger to be avoided, in which case the distributions must return to their original state or the categories must come to be distinguished along the f0 dimension. As discussed above, functional load is a relevant factor in whether merger occurs.

The arrows in Stages 2a and 2b in Figure 1.6 show the directions in which the distributions must be pulled for tonogenesis to fully complete. In the case of the redundant voicing and tonal contrast in 2a, the VOT differences would weaken to yield a marginal (and perhaps eventual loss of a) voicing contrast, whereas in the near-merger case of 2b, the f0 differences must enhance for pitch to be contrastive in place of VOT. Both situations would lead to Stage 3 in Figure 1.6, in which the distributions from the Stage 1 voicing contrast have effectively rotated 90° counterclockwise. These intermediate stages have been directly observed in a number of production and perception experiments with languages currently undergoing tonogenesis, including Seoul Korean (Kim, 2004), Afrikaans (Coetzee et al., 2018), and Phnom Penh Khmer (Kirby, 2014).

[20]This is a simplification for the purpose of illustration, as there could, realistically, be some overlap between the distributions along the VOT dimension, such that there are some voiced tokens with higher VOT than some voiceless ones.

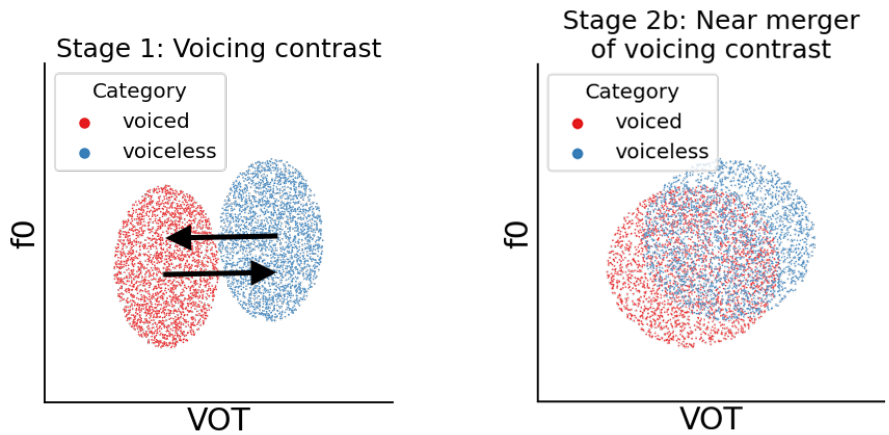


Figure 1.5: Weakening of VOT differences yields near merger of voicing contrast

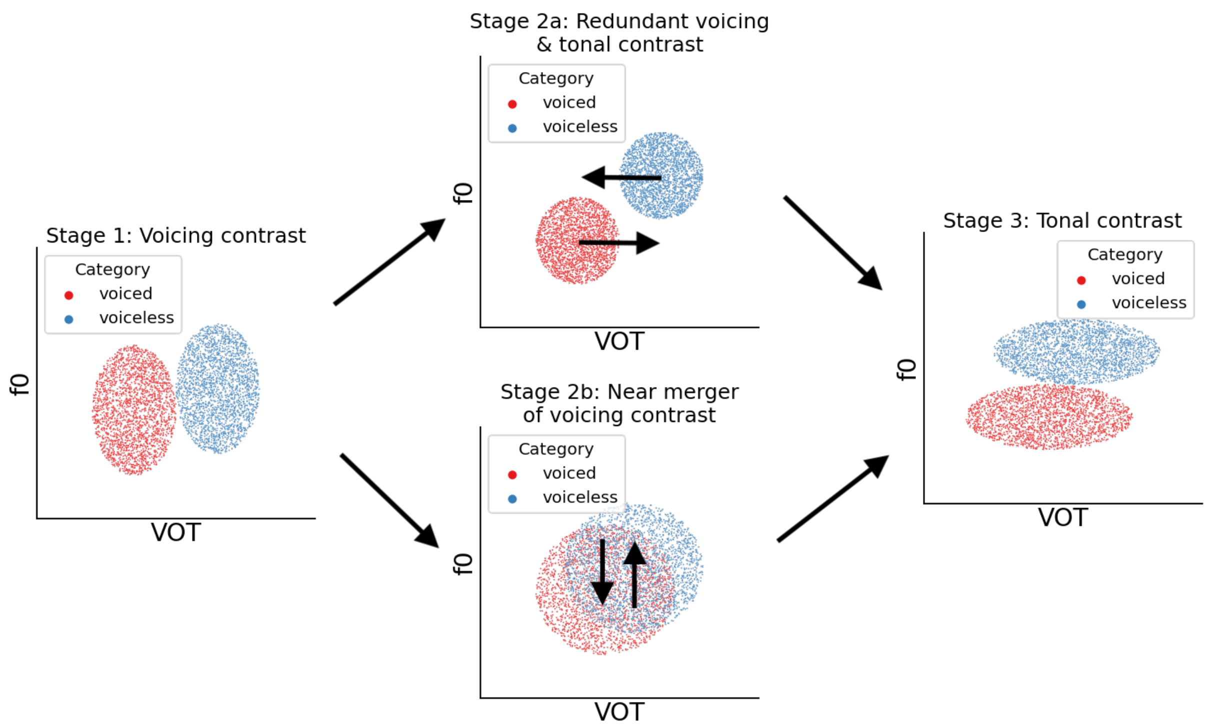


Figure 1.6: Schema of tonogenesis: from voicing to an intermediate stage to tone

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 the process of shifting cues that leads to transphonologization.

1.4 Language interaction at the societal and individual levels

The previous section discussed how the multidimensionality of language contrasts can be a source for language change. However, social factors may also play a role. Large-scale shifts in the sociolinguistic landscape of a language community can lead to shifts in individual language patterns—in turn, these individual-level language patterns can push the distribution of contrasts in directions that are conducive to language change. This section discusses the literature on the effects of macro-level language contact and micro-level individual bilingualism on speakers' phonologies.

Societal-level language contact

The effects of language contact on linguistic systems are visible at all levels of language. The higher the degree of bilingualism in a community, the greater the likelihood there appears to be for structural changes, that is, changes beyond lexical borrowing, to occur. In particular, long periods of societal-level bilingualism appears to be particularly conducive to such changes. For book-length general works on language contact, the reader may refer to Weinreich (1953); Thomason and Kaufman (1988); Thomason (2001); Aikhenvald (2007), and Matras (2009). At the level of phonology, Hinton (1991) describes a case of phonological convergence between languages in the unrelated Takic and Yuman families, whose proto-language phonologies did not resemble one another. Examples of syntactic changes due to contact include the existence of American English verbal constructions in Los Angeles Spanish and Prince Edward Island French (that would be ungrammatical in Mexican Spanish and standard Canadian French), due to bilingualism in English (Silva-Corvalán, 1994; King, 2000), and a switch in word order from SVO to SOV in the Austronesian language of Takia, on the model of Waskia, a Papuan language spoken on the same island (Ross, 2007). Contact effects even permeate up to the discourse level—the reader may refer to Field (1998) or Meek (2012, 47,60) for examples of the maintenance of Indigenous ways of speaking despite a shift to English.

Large-scale effects of language contact result in so-called "linguistic areas", regions of the world in which languages prototypically share a complex of features that are not present in neighboring regions. One such area that is pertinent to the current study is Mainland Southeast Asia, an area that comprises five large families: Sino-Tibetan, Kra-Dai, Hmong-Mien, Austroasiatic, and Austronesian (Henderson, 1965; Matisoff, 2001; Enfield, 2005, 2011). Enfield (2005) enumerates a number of features characterizing the area, including large vowel systems, isolating morphology, lack of inflectional morphology, verb-object word order, and the existence of suprasegmental register and/or tone contrasts, the last of which is a feature that will be focused on for this study. In a sample of 186 MSEA languages, Kirby and Brunelle (2017) find that the Sino-Tibetan, Kra-Dai, and Hmong-Mien languages are all tonal, while about a third of Austroasiatic languages have two-tone or register systems and another third have three or more tones (often co-occurring with voice quality differences). A small number of Austronesian languages in Mainland Southeast Asia have register contrasts, in contrast to non-tonal Insular Austronesian languages, with the exception of some that have developed tone in New Caledonia (Rivierre, 1993, 2001).

Why might tone have developed across so many languages of the Mainland Southeast Asian area? Historical evidence has shown that tonogenesis occurred in Chinese sometime between the first millennium BCE and CE (Sagart, 1999, 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 in these languages to contact with Chinese due to identical-looking tone systems, either implicitly or explicitly (Benedict, 1996; Matisoff, 1973, 88; Pulleyblank, 1986; Sagart, 1999; Ferlus, 2004, 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, 2015a; Brunelle and Kirby, 2015). Ratliff (2015a, 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 (Bereznak, 1995, 93,Premsrirat, 2001, 122, Schuh, 2003, Clements and Rialland, 2008, 72, 74, Hopkins, 2012, 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 and Guion, 2005; Silva, 2006; Kirby, 2014; Kanwal and Ritchart, 2015).

Individual-level bilingualism

Macro-level language contact effects can be understood to ultimately derive from micro-level patterns of individual bilingualism. Structural change due to contact is argued to be a result of bilinguals' *imposition* of features from one language they speak upon another one (van Coetsem, 1988; Winford, 2005). If bilingualism is necessary for structural changes to permeate into a language from another, then an understanding of how bilinguals utilize cues differently from monolinguals is vital to explain how contact may bring about change.

The literature on bilingualism is rife with studies on how speakers monolingual in a language and ones bilingual in that language and another one use cues in a phonological contrast differently. L2 speakers of a language have been shown to use cues differently from monolinguals in both production and perception. The reader may refer to the following studies, many of which are on VOT differences between L1 and L2 speakers of various languages and the last of which examines the realization of Mandarin tones by L1 Korean speakers: Llanos et al. (2013); Liu and Kager (2015); Schertz et al. (2015); Stewart et al. (2018); Vaughn et al. (2019); Lee-Kim (2020). Effects are not merely directional from the L1 to the L2; L2 knowledge can also shift L1 categories in both perception and production, even with short-term or passive exposure. For example, Sancier and Fowler (1997) finds VOT shifts in an L1 speaker of Brazilian Portuguese towards English values after a short stay in the United States and Chang (2010) finds shifts in L1 English speakers' vowel spaces towards Korean values after taking an intensive elementary Korean class. Effects in syntax can also be found: for example, Gürel (2004) finds that L1 Turkish speakers who are bilingual in English transfer properties of English pronouns to Turkish ones. For other work on L2 effects on L1, see Flege (1987); Chang (2019a,b). Even in cases where two languages are being simultaneously acquired, as is the case among children in bilingual communities, there is evidence that different language experiences can yield significant differences in the phonetics of individual speakers: for a case study on these differences among bilingual South Bolivian Quechua-Spanish children with different patterns of language exposure, see Cychosz (2022).

An important sociolinguistic factor that can drive differences in individual patterns of bilingualism is the role of ethnic identity. Labov (1963) demonstrates different realizations of the English diphthongs /ai/ and /au/ in communities on the island of Martha's Vineyard depending on both ethnicity as well as attitudes towards staying on or leaving the island. In another study, Bourhis and Giles (1977) found that Welsh speakers who view Welsh as less integral to their identity reduced their accent more when speaking English, whereas those who view it as more integral increased features of their accent. Fought (2010) discusses the role of ethnic identity in linguistic convergence. Fought finds that middle-class African Americans in Philadelphia show little adoption of the "short-a" pattern characteristic of white Philadelphians, despite everyday interactions. Conversely, she finds that African Americans in Appalachia adopt many features of Appalachian English, but mark their identity with *lexical items* from African American English. The key difference, she suggests, is that African Americans in Philadelphia feel that there is a hierarchy in which they are seen as inferior to whites, whereas African Americans in Appalachia do not feel their identity as being in conflict with being Appalachian. Davidson (2020) demonstrates that differing language attitudes in the overall communities in Barcelona and Valencia with respect to Spanish and Catalan affect the allophonic distribution of intervocalic fricatives in the two languages.

Language change involves a complex web of language-internal factors, including the relationship between phonological contrasts and their phonetic correlates, as well as structural factors in the language and biases in change, interacting with language-external factors, such as individual patterns of bilingualism, which are influenced by social factors such as identity and by larger patterns of language shift. The following section summarizes these patterns in the context of Kuy.

1.5 Summary of the changing situation of Kuy

In §1.2, demographic information from the current study was shown. The results demonstrate a very clear generational shift in the Kuy population in this study: the younger generation is spending more time in school and more of them leave Kuy communities to live in other parts of Thailand. They are also increasingly using Thai and many consider themselves balanced Kuy-Thai bilinguals. The language dynamics are also changing in Kuy society itself due to the increasing presence of Thai in the village through the introduction of Thai at younger ages, the presence of schoolteachers from other provinces, and the increased preference for using Thai with decreasing age. These shifting dynamics pave the way for changes in individual patterns of language usage.

Given the wealth of studies on cue usage by bilinguals in combination with the prehistoric spread of tone throughout Mainland Southeast Asia, we might expect to find that the shift in Kuy communities towards increased usage of Thai, which is tonal, provides a catalyst for the development of tone in Kuy. As the Kuy register contrast is reliably cued by f0 differences, it is natural to look to register as a potential source for the emergence of tone. A number of contemporary studies have investigated language contact effects on f0 usage in Mainland Southeast Asia: 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. Tạ et al. (2022) and Brunelle et al. (2022) also look at two register languages, Chrau and Raglai, and find that speakers who are highly fluent in Vietnamese make little use of f0. 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.

Potential evidence for the influence of Thai/Lao on Kuy comes from a number of studies on the register 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. These studies together suggest that the register contrast in some Kuy communities may be shifting to one that employs pitch more and that this may be due to influence from Thai or Lao.

The role of identity is also a question worth studying. A strong urban-rural hierarchy exists in Thailand, such that those from large metropolitan areas look down on rural people and carry strong stereotypes associated with them. This divide largely corresponds to the divide between Bangkok/Central Thailand and other regions, such as Isan, which is largely rural. Rural people are aware of this hierarchy and the perceptions surrounding it. While some in turn view urban Thais as haughty and pretentious and are proud of their Isan identity, others try to assimilate to Central Thai identity and reject identifying or associating with Isan. Because of the political border between Isan and Laos and the disparity in economic status, some Isan people stress the difference between themselves, the "Thai Isan", and "Lao" people, despite the shared cultural identity, leading both identity, as well as the usage of Lao, a *marker* of identity, to be politicized (McCargo and Hongladarom, 2004; Alexander and McCargo, 2014). In a similar manner, it is possible that members of the Kuy community may also feel the same tension, leading to changing identities and language choices both with respect to *both* Kuy and Lao (not to mention Khmer, which shares a similar negative perception with Lao, also due to the economic status of Cambodia).

Particularly because of more mobility in the younger generation, it is also possible that some younger speakers feel more integrated into Thai society. The continued attempts to unify Thailand by emphasizing a pan-ethnic monolithic Thai identity may be leading the tension between ethnic minority identities and Thai identity to decrease in areas that assimilate more (of course, at the expense of erasure). Across the demographic surveys, 25/51 older participants and 33/49 younger ones responded that they felt equally Kuy and Thai and 4/51 older ones and 3/49 younger ones felt more Thai than Kuy. These numbers account for well over half of the participants, suggesting a relatively high level of integration. This integration of the identities may be a factor in increased structural adaptation from Thai into Kuy, in a perhaps partially parallel situation to the examples of linguistic convergence described in Bourhis and Giles (1977) and Fought (2010).

While other varieties of Kuy have been described as being incipiently tonogenetic (Sukgasame, 2003; Abramson et al., 2004), it remains to be seen whether the Tambon Tum variety of Kuy in this study shows any signs of incipient tonogenesis. Because Thai and Lao use tone contrastively and the situation appears to be trending towards greater usage of Thai, Kuy speakers may be showing greater usage of f0 in the register contrast, particularly if they have greater experience with Thai/Lao or identify more strongly with Thai/Lao identity. It is also possible that these same factors might also catalyze *weakening* of voice quality in the register contrast—Aikhenvald (2020) terms this loss of contrast due to language attrition *negative borrowing*. Alternatively, it is also possible that speakers enhance f0 cues because of contact with Thai, but that these cues are redundantly expressed alongside voice quality.

The overarching goal of this dissertation is to explore whether evidence can be found for the role of multilingualism in shifting cue weights in a phonological contrast and increasing the potential for sound change. To this end, I explore the distribution of phonetic cues in the Kuy register contrast among speakers with varying experiences in different languages as a case study. To investigate the effects of language experience on the distribution of cues, I carry out a production and perception study to gain a holistic picture of how different members of the Kuy community that I worked with utilize phonetic cues in speaking and listening to Kuy and how the usage of these cues may be related to individual speakers' experience with the four different languages of the area. Following Chapter 2, which describes the methodology for the studies, the production and perception studies and their results are discussed in Chapters 3 and 4, respectively. An analysis of the relationship between the production and perception results and implications are then presented in Chapter 5. Finally, Chapter 6 concludes with a summary, a discussion of the larger implications of the results, and suggestions for further study.

Chapter 2

Methodology

The overall question to be explored in this dissertation is whether experience with tonal languages (in this case, Thai and Lao) increases the usage of f0 cues in the Kuy register contrast, given the prominence of f0 in tonal languages. The methods used across the production and perception studies to address this question are explained in this chapter. Each method is explained conceptually, as is their purpose for analyzing the data. I provide toy examples as well and walk the reader through a simplified demonstration to understand each method better. §2.1 begins by addressing my positionality in this research and by providing some background on my relationship with the Kuy community that I worked with. §2.2 then explains how sociolinguistic information about Kuy speakers was gathered, categorized, and quantified. §2.3 covers Principal Components Analysis, a technique for capturing the variation of multiple correlated variables in a reduced number of variables. Lastly, §2.4 covers Linear Discriminant Analysis, a technique for separating categories based on their features and that can be used to classify based on those features.

2.1 Positionality and community

My work in linguistics has been heavily informed by my background as a second-generation Thai-American with Teochew and Hokkien Chinese (both common ethnic profiles for Chinese-descent Thais in urban hubs of Thailand) heritage. I grew up in a trilingual household: my parents speak Thai to one another, but because my father grew up in Hong Kong, he would also speak Cantonese with my sisters and me. When I entered school, I began using English. My sisters and I communicate in a mixture of the three languages, with English contributing the largest component. With multiple languages having been a constant presence in my life, questions related to multilingualism and its relationship with language change have always lingered at the back of my mind over my career and it is with this dissertation that I have finally come to incorporate these questions directly into my research.

My research career is also defined by my work with endangered language communities in two areas of the world: Ryukyuan languages in the Ryukyu islands of southern Japan and Austroasiatic languages in Northeast Thailand. In the former situation, I was squarely an outsider, with no cultural or heritage-wise connection to the communities. In the latter situation, I was also surely an outsider in some ways: I was viewed by some as a visitor from a foreign country, but by others as a visitor from Bangkok. At the same time, however, I was also perceived by many members of the Kuy community as sharing the same Thai national identity. Furthermore, the fact that I was a heritage speaker of Thai led to discussions with various people of a shared experience of language change and loss and hope for rejuvenation. In this way, I occupied a position that was simultaneously both familiar and outside.

I was introduced to the Kuy community in Tambon Tum through scholars from the Research Institute for Languages and Cultures of Asia (RILCA) at Mahidol University in Salaya, Thailand, an organization that collaborates with various endangered language communities throughout Thailand on projects of linguistic and cultural preservation and revitalization. Over the early part of my stay, I spent most of my time getting to know people and familiarizing myself with the Kuy language and culture. I stayed with three different families over my time and practiced using Kuy as much as possible—when communication was hampered, we would switch to Thai. I would spend the day meeting and chatting with people in various everyday settings interspersed with elicitation sessions aimed at unraveling Kuy phonology, with a focus on the Kuy register contrast. By the end of my stay, I was able to reach a very basic conversational level.

The following pictures provide an idea of the setting and various aspects of life in Tambon Tum. Two of the main industries in the Kuy community in Tambon Tum (and in southern Isan in general) are agriculture and textiles. Figures 2.1 through 2.3 provide some common scenery in agricultural life: rice production is central to life in rural Thailand. *Riceberry* is a recently cross-bred purple-colored species of rice that has become a trendy source of nutrients—much riceberry production is carried out in Isan. Water buffalos were traditionally employed in every aspect of rice cultivation, but in the present-day have been replaced by machinery. Figures 2.4 through 2.6 portray the process of raising silkworms, collecting the silk from their cocoons, and the cloth that is produced.

Figures 2.7 through 2.9 showcase Wat Nakharin วัดนาครินทร์, a temple in Ban Khi Nak that is a center of both social and religious life in Tambon Tum. People from the different villages in Tambon Tum regularly gather at the temple for prayer as well as socialization and the temple regularly hosts larger events that are attended by visitors from other parts of Sisaket and Surin provinces. The *naga* (Thai: นาค [nâ:k]), a serpent-like mythical creature originating in Hinduism, which can be seen in Figure 2.7, is a symbol and the namesake of both Ban Khi Nak as well as Wat Nakharin (the *Nak* part of both names). Figure 2.8 shows the temple reception room, where guests to the temple (often monks from other temples) are received and welcomed. This reception room was offered to me by the temple as a quiet room in which I could carry out the experiments, in lieu of a soundproof laboratory space. The reader may refer to Whalen and McDonough (2015) for discussion on laboratory phonetics in the field and Abramson et al. (2015) for another study in Thailand carried out at a temple. Figure 2.9 shows the inside of the reception room, with a tablet that was used for a study. Figure 2.10 is an image of Thongwilai Intanai piloting the perception experiment described in Chapter 4. Thongwilai Intanai is a Kuy speaker from Ban Khi Nak who aided in creating the wordlist for the production experiment in Chapter 3, norming and checking materials and stimuli in both experiments, and recruiting participants.

With this cultural context and introductory understanding of Kuy daily life and culture and the setting in which the studies for this dissertation take place and the context of my own positionality with respect to this research, we will proceed to understand the methodology common to both experiments.

Figure 2.1: Rice paddy in Ban Khi Nak

Figure 2.2: Water buffalos in Ban Khi Nak

Figure 2.3: Riceberry in Ban Khi Nak

Figure 2.4: Raising silkworms

Figure 2.5: Collecting silkworm cocoons

Figure 2.6: Resulting silk products

Figure 2.7: A scene from Wat Nakharin

Figure 2.8: Outside the temple reception room

Figure 2.9: Temple reception room

Figure 2.10: Thongwilai Intanai piloting an experiment

2.2 Sociolinguistic questionnaire

A sociolinguistic questionnaire, based upon Birdsong et al. (2012), designed to capture factors related to language ability, language usage frequency, time spent away from home, and ethnolinguistic affiliation, was carried out in Thai following each study. While it would have been ideal to carry out the questionnaire in Kuy, my Kuy ability was not yet at a level appropriate to effectively gather the necessary information. A version translated to English may be found in Appendix A. Apart from age and gender, 7 other self-reported sociolinguistic factors, described in Table 2.1, were focused on for this study. The languages and ethnolinguistic groups asked about in the questionnaire were Kuy, Thai, Lao, and Khmer.

Demographic information is summarized for the 93 speakers who participated in either the production study, the perception study, or both, and whose data was ultimately analyzed. Figure 2.11 shows the three measures of frequency for each language, binned by 20% intervals. Notably, Lao and Khmer tend to be used much less than Kuy and Thai. The latter two languages show a fair amount of variability in usage frequency in the population in both overall frequency and in usage

Table 2.1: Sociolinguistic Variables

Factor	Description
Years Away	Years spent living in another (non-Kuy speaking) area
Overall Frequency	Overall frequency of using language (0% = never, 100% = all the time)
Friend Frequency	Frequency of using language with friends (0% = never, 100% = all the time)
Family Frequency	Frequency of using language with family (0% = never, 100% = all the time)
Comprehension Level	Ability to understand language (0 = understands nothing, 4 = understands fully)
Speaking Ability	Ability to speak language (0 = cannot speak, 4 = speaks fluently)
Strength of Identification	Identification with ethnolinguistic group (0 = does not identify, 3 = identifies strongly)

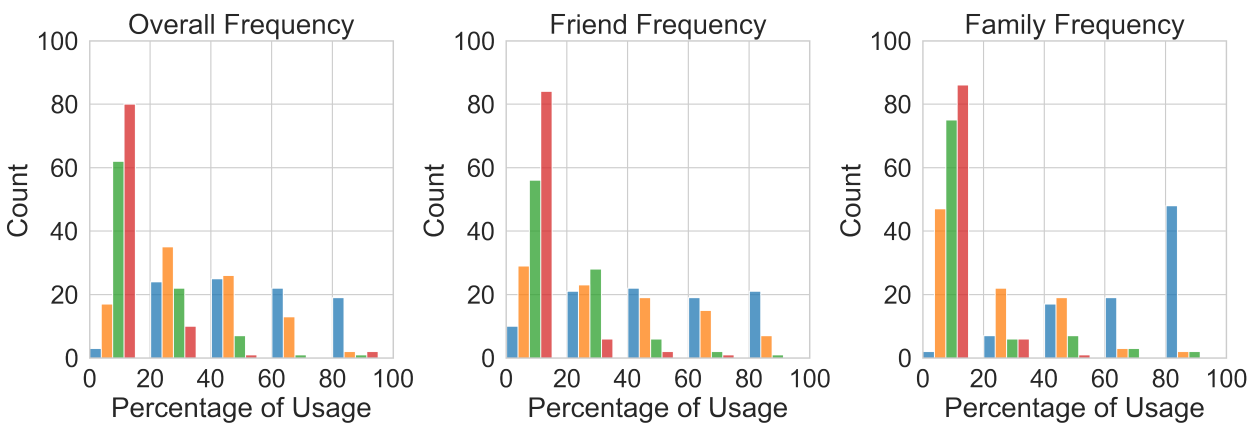


Figure 2.11: Frequency of Language Usage

with friends. Unsurprisingly, language usage with family members is heavily skewed towards Kuy. Figure 2.12 shows the three factors that participants rated by level. Most participants rate themselves as fairly or very proficient in both Kuy and Thai, but there is greater variation in Lao and Khmer ability. 26 speakers reported some knowledge of English [eng], 2 of Vietnamese [vie], 1 of Nyeu [nyl], 1 of Phuthai [pht] (a Southwestern Tai language spoken in Northern Isan), 1 of Mon [mnw] (an Austroasiatic language spoken in Central Thailand and Myanmar), 1 of Yawi [mfa] (a Malayic language spoken at the Thai-Malay border), 1 of Burmese [mya], and 1 of an unspecified Chinese language.

Of the 93 speakers, 49 were from Ban Khi Nak, 22 were from Ban Rong Ra, 20 were from Ban Khi Nak Noi, 1 was from Ban Phlong, and 1 was from Ban Huay Khong. Figure 2.13 shows the

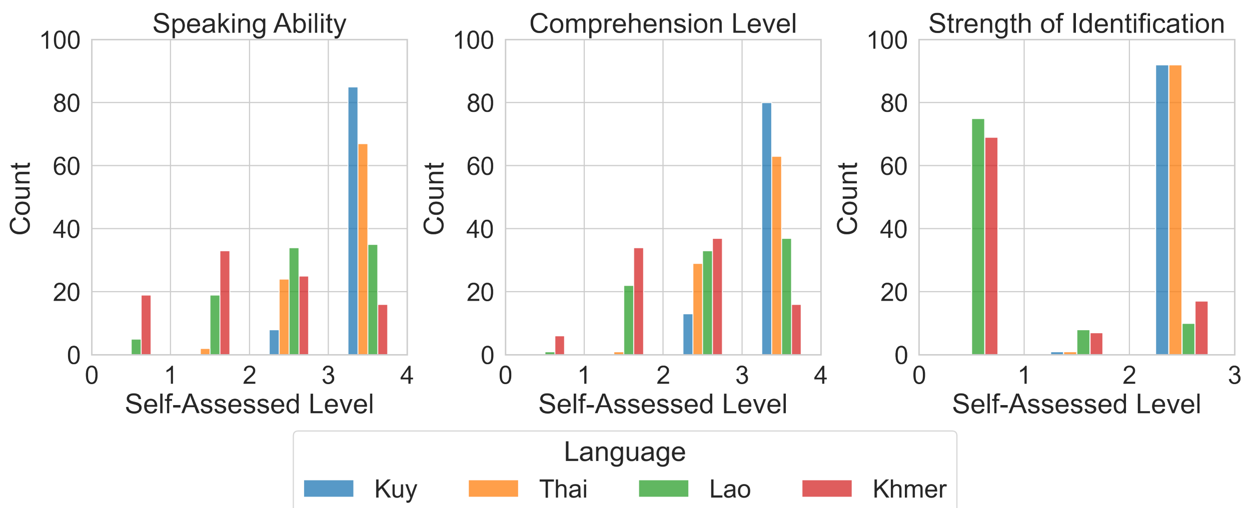


Figure 2.12: Ability level and Strength of Ethnolinguistic Identity

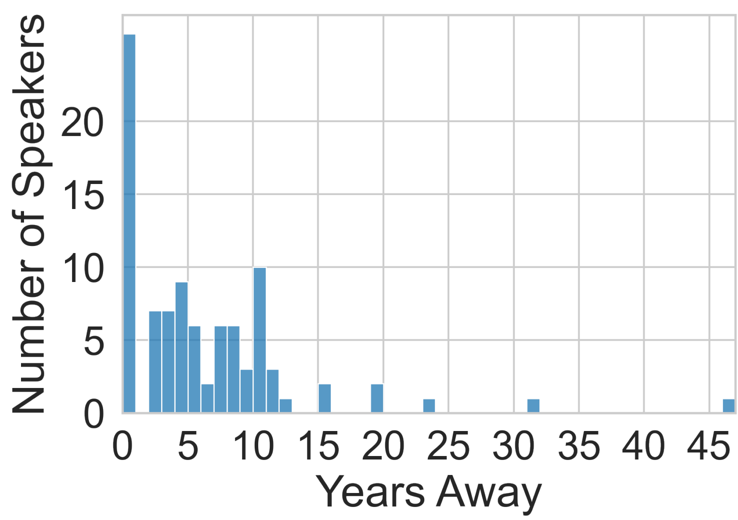


Figure 2.13: Time spent away from home, in years

distribution of time spent away, measured in years. 25 speakers spent 0 years away from home and the maximum time spent away was 47 years. The mean time spent away was 5.9 years with a standard deviation of 7 years, while the median was 4 years. Other places participants spent their lives were mostly in Thailand, although 1 speaker spent time in Laos, 1 in Cambodia, 1 in Taiwan, and 2 in France.

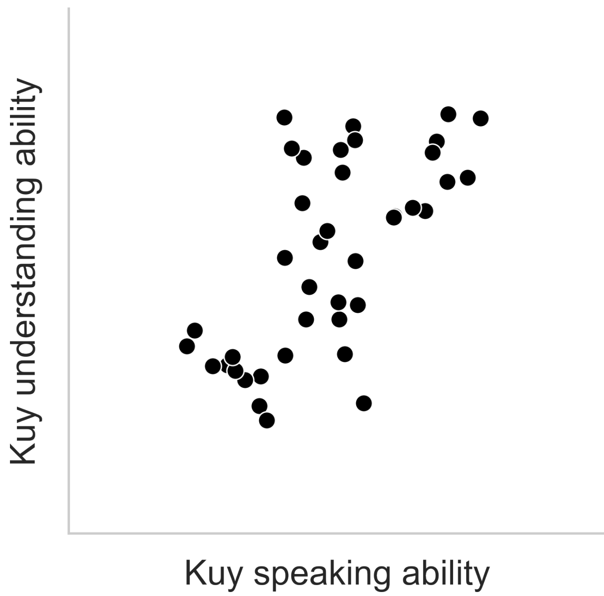


Figure 2.14: Toy dataset for PCA

2.3 Principal components analysis

Principal component analysis (PCA) is an unsupervised machine learning algorithm used to reduce a number of factors (or *features*) to a smaller number of orthogonal dimensions that captures the variance between the factors. It is particularly useful when at least some of the factors are expected to be highly correlated with each other. To understand the process of PCA, Figure 2.14 provides a toy dataset of 40 tokens. For simplicity, only two factors are provided: (1) ability to speak Kuy and (2) ability to understand Kuy. Intuitively, we would be inclined to expect that speaking and understanding ability in a language are likely to be positively correlated as in Figure 2.14. Carrying out a PCA allows us to investigate the possibility of combining these two variables into one for analysis.

First, the PCA attempts to find a linear combination of the two factors that maximally captures variance in the data. Figures 2.15 and 2.16 demonstrate two different lines (in solid red) that the algorithm might evaluate. The dotted red lines show the variance of the points when projected to the solid line. It can be seen that the line in Figure 2.16 yields a greater variance than the one in Figure 2.15. The line that maximizes the variance is known as the *first principal component*, or PC1. Intuitively, because of the high positive correlation between the two factors, it makes sense that a fairly positive slope would capture the information for both these factors well.

Following the determination of PC1, the algorithm will then calculate the second principal component (PC2) in the same manner to find the line that accounts for the second highest variance, while maintaining the restriction that it must be perpendicular to PC1 (see green line in Figure 2.17). The total number of principal components is equivalent to the number of factors, but the decision for which principal components to use in follow-up analyses ultimately depends on the problem that is being explored and the analyzer's judgment. The thought processes for these decisions in the analysis of the production and perception data will be discussed in their respective sections.

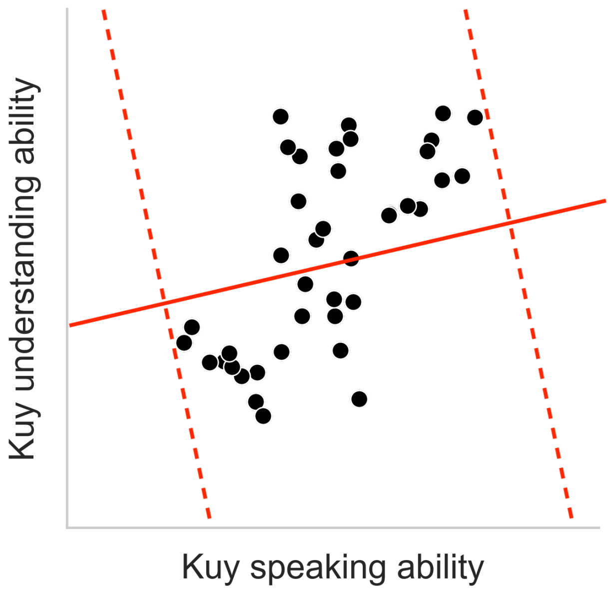


Figure 2.15: Attempt 1 to find PC1

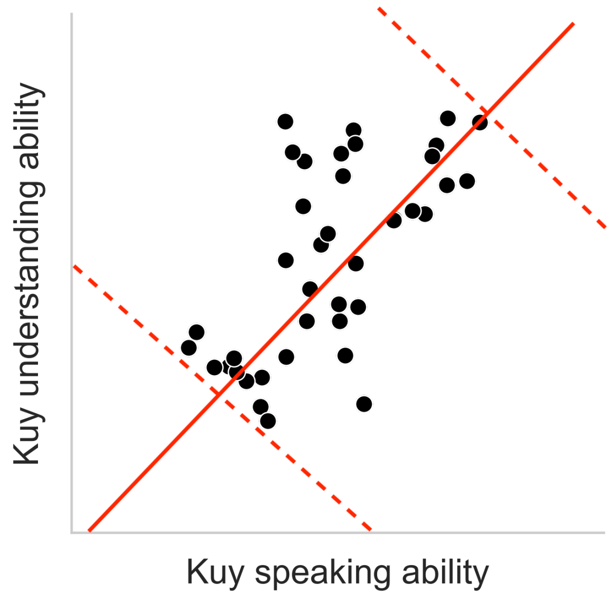


Figure 2.16: Determination of PC1

As much of the sociolinguistic information collected in the survey was expected to be correlated to language usage, a PCA was carried out on the sociolinguistic variables, using the `FactoMineR` package (Lê et al., 2008) in R (R Core Team, 2018) to reduce the data to a tractable number of factors for analysis. Many of the variables (see Table 2.1) 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 the non-tonal languages, Kuy and Khmer, and with respect to the tonal languages, Thai and Lao. This differential measure was preferred over 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 measure that would capture the *relative* level of usage of, ability in, and identification with non-tonal languages/communities that use a non-tonal language *as compared to* tonal languages/communities that use a tonal language.

The final transformed sociolinguistic variables that were input into the PCA are explained in Table 2.2. Values were scaled by dividing z-values by 2, following Gelman (2008), who proposes this method for statistical modeling to allow for direct comparison with binary predictors.

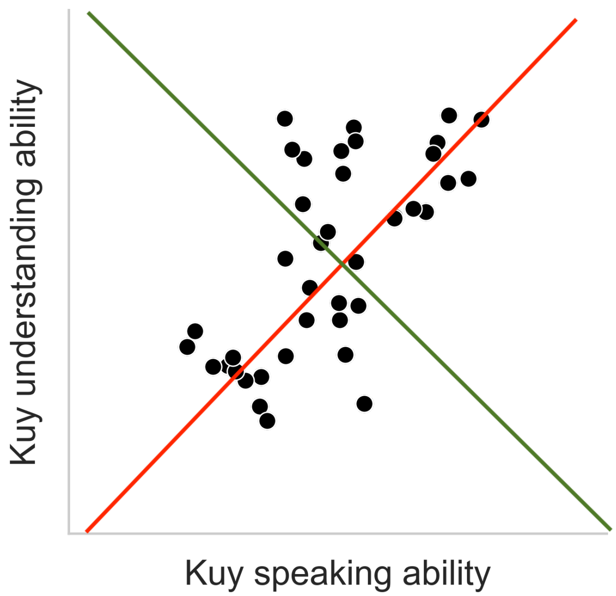


Figure 2.17: Determination of PC2

Table 2.2: Sociolinguistic Variables for PCA

Factor	Description
Age	Participant's age in years.
$\sqrt{}$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).

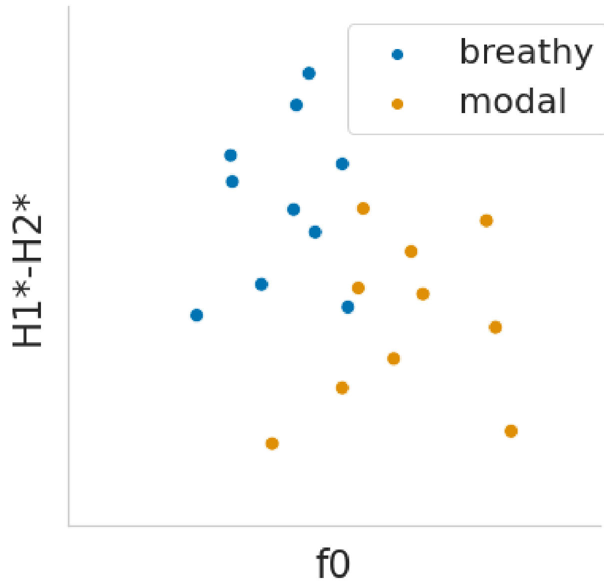


Figure 2.18: Toy labeled dataset for LDA training

2.4 Linear discriminant analysis

Linear discriminant analysis (LDA) is a supervised machine learning algorithm that attempts to search for an optimal linear combination of features to separate two or more classes by *maximizing* the distance between the means of the classes and *minimizing* the variance within each class. In order to understand how the LDA works, we will look at Figure 2.18 as a toy training dataset with 20 tokens. Here we take a simple example with only two of our measures, H_1*-H_2* and f0, each of which can be considered a feature. Each token is plotted onto the graph, using its f0 measure as the x-value and its H_1*-H_2* measure as the y-value. Because this method is supervised, the *class* (in this case, whether the token has a breathy or modal voice quality) is labeled for the model.

In training, the model is initialized with a random linear combination of both features, represented by the solid black line in Figure 2.19. This line noticeably does not separate the modal and breathy classes well, as both classes are well-represented both above and below the line. The model employs an optimization algorithm in order to recalibrate the line and reevaluate the model fit. This process repeats until it has reached either the maximum number of iterations or until it has found an optimal solution. Figure 2.20 illustrates an optimal solution, in which all but one modal token are classified correctly.

In the test phase, the output of the LDA training is used to classify new data whose labels it cannot see. The farther a token is away from the line, the greater the probability is that the model will classify it as the category represented by that side of the line. Tokens close to the line will have a more balanced probability of being assigned to either class. Figure 2.21 shows an example test phase: the model determines, for each token, the probability that it belongs to each class. Figure 2.22 shows the labeled test set—each token has been labeled with the category with the higher probability (as shown in Figure 2.21). Here, each token's *actual* class is indicated by its color. Every token is labeled correctly, except for the token being pointed to by the orange arrow. This token is breathy but is misclassified as modal. Given this 5 point test set, the model has an 80% accuracy rate.

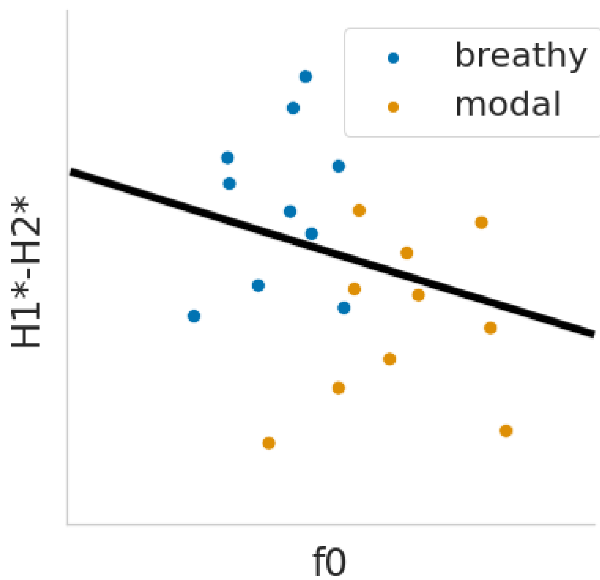


Figure 2.19: LDA training: initialization

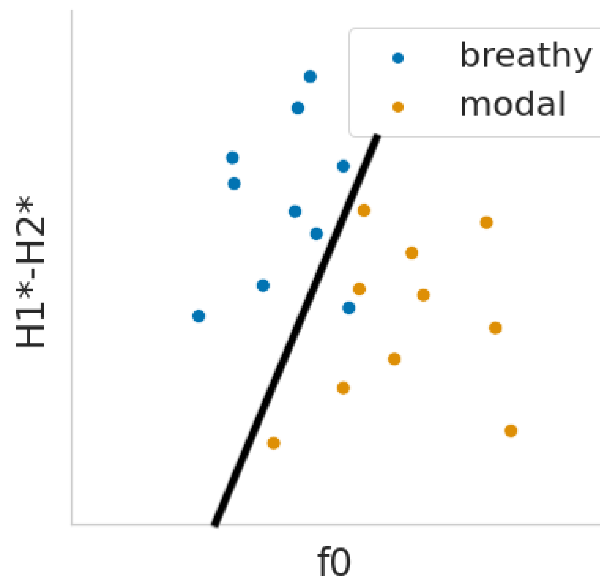


Figure 2.20: LDA training: final result

We can now generalize this model to one with more features: if 2 features are provided for a 2-category classification problem, the categories may be separated by a 1-dimensional line. If 3 features are provided, however, the categories will have to be separated by 2-dimensional plane. *Hyperplane* is the general term for the linear combination of features separating the categories. For a given dataset with n features, the hyperplane will have $n-1$ dimensions.

In splitting our data into training and test sets, it is possible that a given split can create biased samples. In particular, since we are working with an endangered language, there are fewer samples than are ideal for a machine learning problem. As such, one method to make our LDA more robust is to employ k-fold cross-validation. In this methodology, we split our dataset containing n tokens into k equal subsets, each of which will have a size of $\frac{n}{k}$ tokens, rounded up or down to the nearest integer as necessary. Each subset comprises a test set, while the remaining tokens in the full dataset comprise its companion training set. This method allows us to run the model k number of times and to average out the test results, to minimize bias. For the current study, 10-fold cross-validation was utilized.

LDA, carried out through the `scikit-learn` library in Python 3.7 (Van Rossum and Drake, 2009), was used to approximate cue weights for both production and perception, 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 and Clare, 2020). The training and test process involved 10 k-fold cross-validation. In these studies, a classifier was trained, for each individual, to determine whether each token was *modal* or *breathy*, given the acoustic measures for the token. The accuracy of the classifier for a given cue was used as a proxy for the weight of that cue.

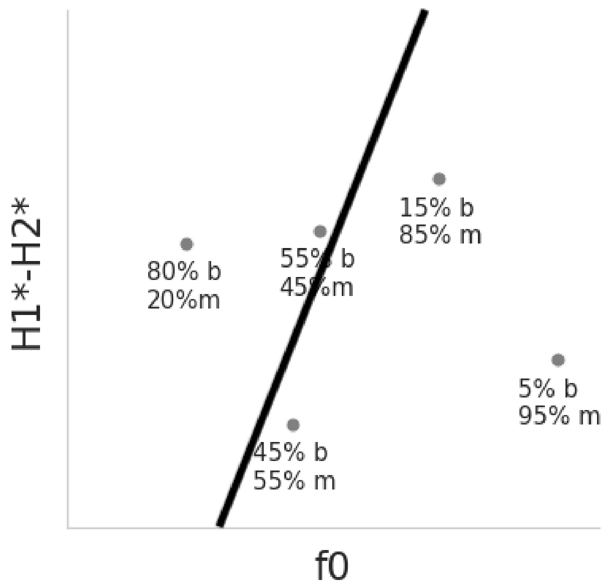


Figure 2.21: LDA test phase: model hypotheses

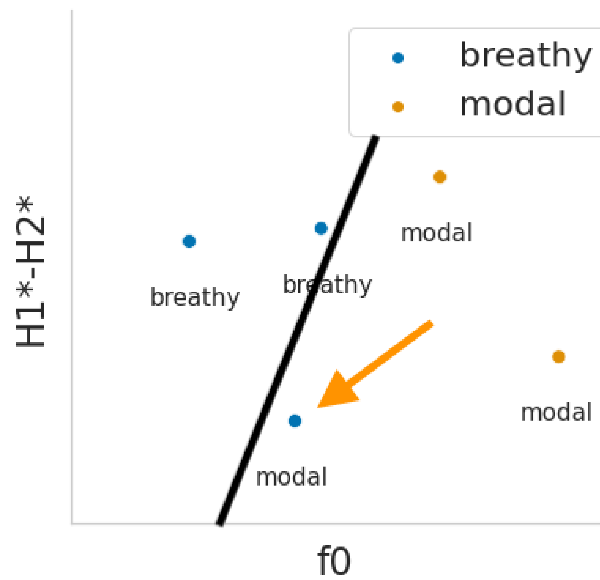


Figure 2.22: LDA test phase: labeled values compared to actual values

This chapter has described methodology that is shared across the experiments. For analyses specific to each specific study (for example, linear mixed effects regression for the production experiment and logistic mixed effects regression for the perception experiment), refer to the methodology section in the relevant chapter.

Chapter 3

Experiment 1: Kuy Register in Production

The first study, carried out in 2018, was designed to assess how acoustic correlates of register manifest in different Kuy speakers and to test whether experience with tonal languages affects the distribution of the acoustic correlates. §3.1 details methodology that is specific to the production experiment and explains how the methodology common to both experiments was applied. §3.2 lays out the results of the production experiment. The results are then interpreted in §3.3 and the findings are summarized in §3.4.

3.1 Methodology

Participants

75 participants were recruited 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 after 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 (n = 1), extreme difficulty with the task (n = 2), recording issues (n = 4), and producing fewer than ten analyzable (see below for determination of analyzability) unique words (n = 2), leaving 66 participants (40 from Ban Khi Nak, 14 from Ban Rong Ra, and 12 from Ban Khi Nak Noi). These participants' ages (by decade) and genders are provided in Table 3.1.

Table 3.1: Participants by age and gender

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

Words

The words used in the experiment consisted of 58 unique words, consisting of 31 target words and 27 distractor tokens. The 31 target tokens consisted of 1 minimal triplet and 14 modal-breathy minimal pairs. The minimal triplet consisted of a word with a modal vowel preceded by an aspirated stop (this combination will be called "aspirated modal" for ease), one with a modal vowel preceded by an unaspirated stop (this combination will be called "unaspirated modal" for ease), and one with a breathy vowel (to be called "breathy" for ease). The minimal pairs consisted of 2 aspirated modal vs. breathy pairs and 12 unaspirated modal vs. breathy pairs. As mentioned in §1.2, unaspirated and aspirated consonants are neutralized before breathy vowels. There are also 2 sonorant pairs. Words were balanced only for voice quality, but not for segments. Of the target words, 4 have historic[1] syllabic nasals. Loss of the syllabic nasals leads to the emergence of some new minimal pairs (ex. /ŋkɛːŋ/ > [kɛːŋ] 'waist' vs. /kɛ̤ːŋ/ 'side). 7 vowel qualities (/iː eː ɛː a ɑ oː uː/) and their breathy counterparts are represented in the minimal pairs.

The remaining 27 words were distractor tokens. These were chosen to observe more vowel qualities as well as phenomena for future research, including the dropping of syllabic nasals and the merging of /tr/ clusters to /kr/ and of coda /r/ to /l/, all of which show age-graded variation. All the vowel qualities in Kuy are represented between the target and distractor words, although some short or long counterparts are missing. Wordlists for the target words and distractor tokens as well as the distribution of onsets, nuclei, and codas in the target words may be found in Appendix B.

Procedure

The task in the current production study involved embedding the words in a carrier sentence, presented in Thai. Because participants in this population were new to linguistic experiments and several were elderly, I designed the experiment with two limitations in mind: the task must not be cognitively demanding and the experiment must not last too long. To address the first limitation, participants were asked to construct their own carrier sentence by translating the example sentence in (1) from Thai into Kuy and to use that frame for each sentence, only replacing the word "water" with the target or distractor word. (2) is one common translation. Having the participant translate the sentence facilitated naturalness as participants varied in preference for some optional elements such as presence or absence of the complementizer /paj/, choice of the word /pnaːj/ or /kʰam/ to translate 'word', and choice of the word /paːj/ or /waw/ to translate 'say'.[2] The target or distractor word retained prominence regardless of the sentence used. Pictures of the words were provided below the sentence to aid in elicitation of the intended word. Figure

[1] I use this term rather than "underlying" as there is no evidence to suggest that it is part of the phonemic representation of speakers who do not realize syllabic nasals.

[2] /pnaːj/ and /paːj/ are both native Kuy words (the former being derived from the latter through the addition of the fossilized nominalizer infix *-n-*. The complementizer /paj/ is also likely derived from /paːj/), while /kʰam/ is from Thai/Lao and /waw/ is from Lao. /waw/ can also mean 'speak'.

3.1 shows the screen that participants saw for the example sentence with /diaʔ/ ‘water’, while Figure 3.2 shows what participants saw for the example sentence with /n̩trɛ̤:l/ ‘egg’.

(1) Example Thai sentence

ฉัน	พูด	คำ	ว่า	**น้ำ**	ให้	เขา	ฟัง
cʰǎn	pʰû:t	kʰām	wâ:	**ná:m**	hâj	kʰǎw	fāŋ
1SG	say	word	COMP[3]	**water**	for	3	hear

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

(2) Example Kuy translation (in Mahidol orthography)

ไฮ	เวา	ปะนาย	ไป	**เดียะ**	ออฺน	เนา	จะงัด
haj	waw	pna:j	paj	**diaʔ**	ɑ:n	naw	cŋat
1	say	word	COMP	**water**	for	3	hear

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

Figure 3.1: Example sentence in (1). Instructions above say “Please translate the following sentence into Kuy”. The example Thai word /ná:m/ ‘water’ is in red. The expected Kuy word is /diaʔ/.

Figure 3.2: Example sentence from task. The example word /ná:m/ ‘water’ has been replaced with /kʰàj/ ‘egg’ (in red). The expected Kuy word is /n̩trɛ̤:l/.

After establishing the carrier sentence, I walked the participant through each word in the wordlist once as a familiarization round, confirming that they knew them. The participant then

[3] Complementizer

completed 5 trial rounds alone, lasting between 15 and 30 minutes (with older speakers generally taking longer) with an optional break after round 3. The wordlist was randomly shuffled each round.

Files were marked for whether the uttered word was the intended target and, for the 5 words with potential syllabic nasals, whether the nasal was existent. Minimal pairs were included in the analysis only if the speaker produced at least 2 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. /~~(ɲ̩)~~chuːn/ 'to hide' and /cṳːn/ 'to send'), but in the case of /(ŋ̩)kɛːŋ/ 'waist' vs. /(ŋ̩)kɛ̤ːŋ/ 'side', there were some speakers who pronounced both with the nasal: the pair was included as long as both words had at least two tokens *matching* in presence or absence of the nasal. There were 155 (31 targets $\times$ 5 rounds) potential tokens in total per participant, although no speaker produced all 155 tokens. All together, 5125 tokens were available for analysis. Following this task, the participant answered a series of demographic questions discussed in §2.2, which took between 10 and 20 minutes.

The experiment was presented on a Google Nexus 10 tablet. The participant's voice was recorded with an AKG C544-L head-worn condenser microphone connected to an H4n Zoom recorder.

Analysis

Acoustic processing

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 12 undergraduate research assistants. For each token, 8 acoustic measures were taken at 1 ms intervals over the course of the vowel using VoiceSauce, a software for automatically calculating voice measures (Shue et al., 2011). These measures are f0, F1, CPP, and 5 harmonic measures (H_1*, H_1*-H_2*, H_1*-A_1*, H_1*-A_2*, H_1*-A_3*). 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 is correlated 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 increases. Higher open quotients and steeper spectral tilt are associated with a breathier voice quality (Holmberg et al., 1995; Hanson, 1995, 1997; Hanson and Chuang, 1999; Henrich et al., 2001; Gobl and Ní Chasaide, 2013). The asterisks following the spectral measures indicate correction for formant frequencies and bandwidths, which also account for age and gender differences between speakers (Iseli et al., 2007). CPP, *cepstral peak prominence*, is a proxy for the *harmonics-to-noise ratio* (HNR). Breathier voice qualities have lower HNR and CPP values (Hillenbrand et al., 1994). The reader may refer to the paragraph referencing Table 1.11 for literature on languages for which these measures differentiate register. All of the spectral tilt measures were ultimately combined into one (to be called H_1*(-A_n*)) through a PCA on all the acoustic variables except for f0 and F1 (see §3.2), leaving 5 measures for analysis: f0, F1, CPP, H_1*-H_2*, and H_1*(-A_n*).

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 manually 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, the formant ceiling and number of formants were set at 5000 Hz and 4.5, respectively, following heuristics laid out by Skarnitzl et al. (2015). After inspection, the ceiling was shifted up or down as necessary to minimize errors. These f0 and formant values were the basis for VoiceSauce's calculation of the 5 harmonic measures and CPP. All measurements were taken at every millisecond with a sliding window of 25 ms.

The resulting measurements were first cleaned up by seeking to minimize errors. First, a moving median filter with a size of 15 ms was applied to smooth out sudden tracking jumps. Second, values of zero (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 were removed (6.8% of the remaining dataset). Ultimately, 6.89% of the dataset was removed. Because speakers may speak at different rates and vowels vary in their length, time was normalized by binning measurements for each file into 20 time intervals, leaving 102,500 data points.

Voice quality measures vary largely across individuals (see Klatt and Klatt, 1990; Hanson, 1995, 1997; Hanson and Chuang, 1999; Davies and Goldberg, 2006; Ma and Love, 2010 for literature on gender differences and Biever and Bless, 1989; Linville, 1992, 2002; Lee et al., 2015 for age differences, respectively), and so the values were scaled by speaker, with Gelman's 2008 standardization procedure (see §3.2), for comparability and statistical modeling. For F1, the values were additionally normalized by vowel height. For modeling purposes, Hertz values for f0 and F1 were also converted into semitones[4] to better approximate auditory distance (Nolan, 2003).

Linear regression

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 and Schoenberg, 1966)), Register, Gender, Tonal Language Experience, and Time Away on the five acoustic measures: f0, F1, CPP,

[4]The conversion formula is below, where Hz_{ref} 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.

$$semitones = 12 \times \log_2 \frac{Hz}{Hz_{ref}}$$

H_1*-H_2*, H_1*(-A_n*). Semitones were used for f0 and F1. 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.

Linear discriminant analysis (LDA)

Individual differences were explored by quantifying cue weights for the same five acoustic measures as in the linear regression through the use of Linear Discriminant Analysis (LDA) (see §2.4). For the production experiment, the inputs for the LDA were each of the aforementioned five continuous acoustic measures—f0, F1, CPP, H_1*-H_2*, H_1*(-A_n*)—for each token. For each measure, the average value across the 20 timepoints was taken as the data point for each token. The outputs were the register categories *modal* or *breathy*. As in the linear regression analyses, the scaled values for all the measures are used. Semitones are used for f0 and F1. 6 LDAs were run for each of the 66 participants in the study: one for each of the measures and one using the three voice quality measures—CPP, H_1*-H_2*, and H_1*(-A_n*)—together as the inputs. This last LDA will be called the *Voice Quality (VQ) LDA*.

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. The intuition for the LDA on the production results is as follows: the LDA may be thought of as a naive listener. In the training phase, the LDA learns the modal-breathy contrast using only the data given to it: for example, for each token, it is given the average f0 for each token and told what register that token is. In the test phase, the LDA applies what it learned from the training phase. For each token in the test set, it will guess the register of the token given limited information: for example, *only* the average f0 value of the token (and no voice quality or F1 information). The percentage of tokens for which the LDA guesses the register accurately is calculated and is considered a proxy for the weight of the given acoustic cue. Under the logic that the LDA as a "listener" should be able to more accurately guess the class a token belongs to if a cue is a good separator of the classes, a more accurate LDA accuracy should indicate a heavier cue weight.

Pearson's r was calculated between these cue weights and Tonal Language Experience as well as Time Away to test whether there is a correlation between language usage and production cue weights. Correlations between the weights of f0 and the other 5 cues were also calculated in order to test whether there is a tradeoff between f0 and other register cues.

Hypotheses

Table 3.2 summarizes the expected patterns for each of the acoustic measures being analyzed, given crosslinguistic patterns for the acoustic correlates of these registers.

Because Thai is a tonal language that does not use voice quality, I hypothesize that Kuy speakers who use tonal languages more or who have spent more time away from home will show greater f0 differences but smaller voice quality differences between the registers in the linear regression and higher accuracy scores in the f0 LDA models but lower accuracy scores in the voice

Table 3.2: Voice quality measures and expected correlations with register

	Explanation	Expected pattern
f0	fundamental frequency (Hz), correlate of pitch	modal > breathy
F1	first formant (Hz), correlate of vowel height	modal > breathy
H_1*-H_2*	amplitude of first harmonic - amplitude of second harmonic (dB), correlate of open quotient	breathy > modal
H_1*(-A_n*)	amplitude of first harmonic (- amplitude of loudest harmonic of n^{th} formant), measures of spectral tilt	breathy > modal
CPP	cepstral peak prominence, measure of degree of periodicity	modal > breathy

Table 3.3: Hypothesized results for analyses

	Cue	↓TLE/Time Away	↑TLE/Time Away
Linear regression	f0	less difference between registers	more difference between registers
	VQ	more difference between registers	less difference between registers
LDA	f0	lower accuracy	higher accuracy
	VQ	higher accuracy	lower accuracy
Contrast		greater VQ, less f0 usage	greater f0, less VQ usage

quality LDA models than Kuy speakers who do not use tonal languages as much or who have spent less time away from home. These hypotheses are summarized in Table 3.3.

3.2 Results

Preprocessing of sociolinguistic information

All speakers are bilingual in Kuy and Thai and most have at least some knowledge of Lao and Khmer. Only 1 participant reports not understanding Lao, while 6 report not understanding Khmer. In terms of speaking ability, 3 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.

The distribution of time spent away from home (measured in years) may be seen in the left graph of Figure 3.3. 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 number of years spent away are 0.5 and 47, respectively.

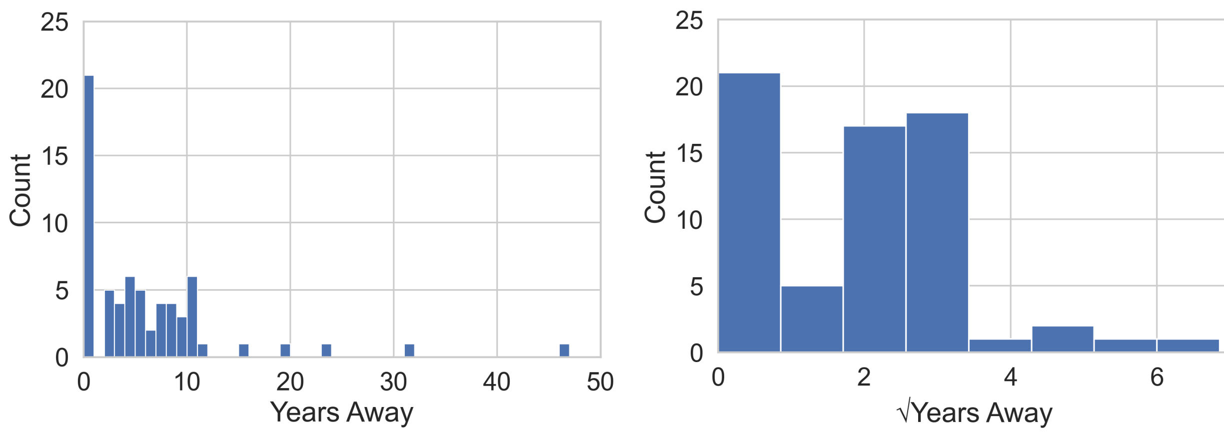


Figure 3.3: Histograms of time spent away by participants (left: raw; right: square-rooted)

Because of the heavy right skew (3.12[5]) for the number of years away people have spent away from home, the number of years spent away was square rooted for analysis. The distribution of $\sqrt{}$Years Away can be seen in the right graph of Figure 3.3 (mean: 1.84, median: 2, skew: 0.57). The participant demographics (see Figures 2.11 through 2.13) show that 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.

Summary Statistics

Table 3.4 lays out the target pairs/triplet produced in the study, organized in decreasing order of the number of speakers that produced at least 2 viable tokens of both members of the set. For all the pairs with syllabic nasals, except one, the syllabic nasal is crossed out in this table since its existence would create non-viable pairs. The /(ŋ)kɛːŋ/ 'waist' ∼ /(ŋ)kɛ̤ːŋ/ 'side' pair is split up between the few speakers who have syllabic nasals for both words and those who lack it for both word. The full minimal triplet was rare as a set, as many younger speakers were not very familiar with the /tʰeː/ 'jar' word while many older speakers preserved the syllabic nasal in /n̩te;/ 'to say'.

Reasons for failing to produce a viable token included:

1. Forgetting the intended translation
2. Saying a close synonym: ex. /sluːɲ/ for /tʰeː/ 'jar'
3. Saying a compound: ex. /plaj toːŋ/ (lit. 'fruit coconut') for /toːŋ/ 'coconut'

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

Table 3.4: Number of speakers per minimal pair/triplet

		Number of Speakers by Decade				
Kuy	Gloss	20s	30s	50s	60s	Total
ti: ∼ ti̤:	old ∼ tall	16	16	18	16	66
taʔ ∼ ta̤ʔ	grab ∼ to place under	16	16	17	16	65
tah ∼ ta̤h	divorce ∼ slap	15	14	18	14	61
pu:ʔ ∼ pṳ:ʔ	sun ∼ beard	15	15	14	16	60
to:ŋ ∼ to̤:ŋ	coconut ∼ male (animal)	15	15	14	14	58
lu: ∼ lṳ:	to howl ∼ thigh	14	11	16	14	55
tʰe: ∼ te̤:	jar ∼ no	3	8	10	9	30
n̥te: ∼ te̤:	to tell ∼ no	9	2	-	-	11
tʰe: ∼ n̥te: ∼ te̤:	jar ∼ to tell ∼ no	2	3	-	-	5
pi:l ∼ pi̤:l	flower ∼ to spin	8	9	5	5	27
n̥cʰu:n ∼ cṳ:n	to hide ∼ to send	12	8	1	2	23
po:t ∼ po̤:t	swelling ∼ too much	10	7	3	-	20
ku: ∼ kṳ:	to be at ∼ every	7	6	4	2	19
pʰo:m ∼ m̥po̤:m	fragrant ∼ just (now)	9	6	2	-	17
tpat ∼ tpa̤t	west ∼ six	5	4	4	1	14
lɑp ∼ lɑ̤p	to return ∼ dusk	3	3	3	1	10
ŋ̊kɛ:ŋ ∼ kɛ̤:ŋ	waist ∼ side	7	2	-	-	9
ŋkɛ:ŋ ∼ ŋkɛ̤:ŋ	waist ∼ side	2	1	-	1	4

4. Misreading the word: ex. /abu:ŋ/ 'spoon' for /n̥chu:n/ 'to hide' because of reading ซ่อน /sɔ̂n/ as ช้อน /tɕɔ́:n/

5. Difficulty of imaging some words and the translation by itself was not always clear: for example, /m̥po̤:m/ 'just (now)' was translated into Thai as เพิ่ง /pʰɤ̂ŋ/ 'just (now)'. Without any context, this word was confusing to some participants. To aid participants, the word was introduced in training with an image of a person yawning in bed and the participant was told to think of the context as 'just woke up'. Because the yawning itself was salient in the image, a not uncommon response was /sʔa:p/ 'to yawn'

Older speakers were more likely to fail to produce viable tokens for any of the above reasons, perhaps at least partially due to lower working memory. The greater tendency for older speakers to produce syllabic nasals also led to fewer pairs. The weaker representation for many of the pairs among older speakers may be seen in Table 3.4.

Voice Onset Time

Of the 5125 files, 4542 contained a target word with a stop onset. The durations of the voice onset time (VOT) for these stops are summarized here. The VOT of voiceless unaspirated stops preceding modal vowels, voiceless aspirated stops preceding modal vowels, and voiceless stops preceding breathy vowels are significantly different (F = 1857.57, $p < .001$). However, the VOT of voiceless stops preceding breathy vowels (μ = 26.75 ms, SD = 15.86 ms, n = 2262) is closer to unaspirated voiceless stops (μ = 16.61 ms, SD = 8.68 ms, n = 1938) than to aspirated ones (μ = 63.33 ms, SD = 31.13 ms, n = 342). The VOT distributions for each type of stop are displayed in Figure 3.4.

Duration

Table 3.5 and Figure 3.5 break down and visualize the means and standard deviations of vowel durations from the data by vowel and voice quality. 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.

Mean f0, H_1*-H_2*, and F1 trajectories by vowel

Figure 3.6 shows mean f0, H_1*-H_2* (a reliable correlate of voice quality crosslinguistically), and F1 trajectories alongside 95% confidence intervals for each vowel. Scaled values (described in §3.1) are used to normalize for interspeaker and vowel quality (in the case of F1) differences. Confidence intervals for /ɛː/ and /ɑ/ are large because they are represented by few tokens. While some register languages, such as Arem (Tạ, 2021), show f0 differences in only some vowels, it is clear that modal voice has higher f0 overall than breathy voice in Kuy, regardless of vowel quality. Voice quality and F1 differences are also significant in the expected directions for all vowel qualities.

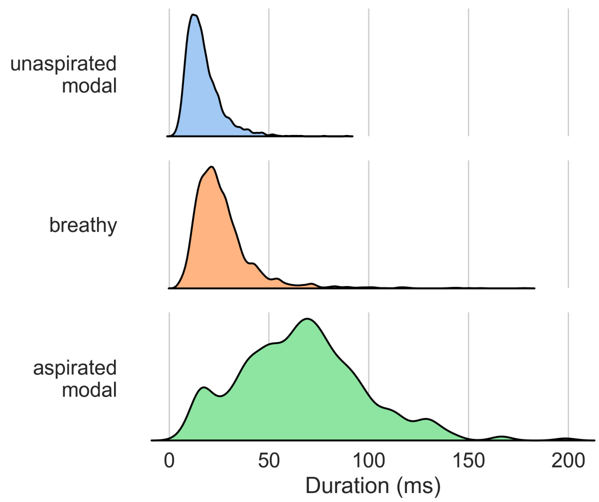


Figure 3.4: VOT by stop type and voice quality

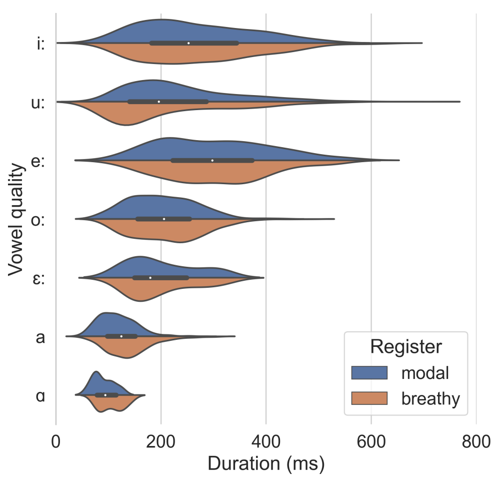


Figure 3.5: Duration by vowel quality

Table 3.5: Mean vowel durations (ms)

	Modal			Breathy		
Vowel	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
ɛ:	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

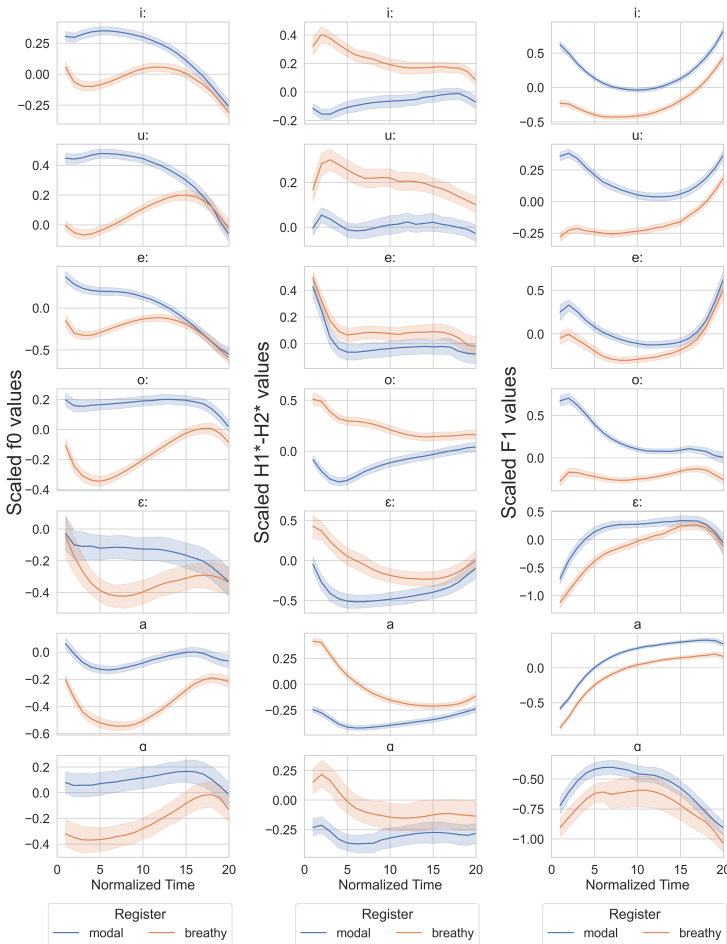


Figure 3.6: f0, H_1*-H_2*, & F1 trajectories by vowel quality

Table 3.6: Mean f0, H_1*-H_2*, & F1 values by vowel quality & register

	f0 (Hz)	
Vowel	Modal	Breathy
i:	174.96	169.16
u:	179.95	170.98
e:	167.92	161.34
o:	175.17	166.46
ɛ:	176.86	167.8
a	170.28	161.99
ɑ	192.15	184.38

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

	F1 (Hz)	
Vowel	Modal	Breathy
i:	387.54	350.11
u:	379.53	351
e:	450.1	428.26
o:	470.91	424.19
ɛ:	600.81	567.13
a	926.32	881.34
ɑ	703.97	649.68

f0 trajectories by environment

Figure 3.7 looks at onset effects on (scaled) f0 trajectories, taking into account voice quality. Results are divided by generation to observe generational differences. The older generation consists of speakers between 50 and 70, while the younger one consists of speakers between 20 and 40. f0 following aspirated stops is slightly higher than after unaspirated stops, and in turn much higher than after breathy stops. Interestingly, f0 following sonorants is higher overall, particularly for modal voice. Contour shapes do not differ much by generation, but starting and ending values do. Note that aspirated stops are represented only by 3 words and sonorants only by 4 words, and so the aspirated and sonorant f0 trajectories should not be considered necessarily meaningful or

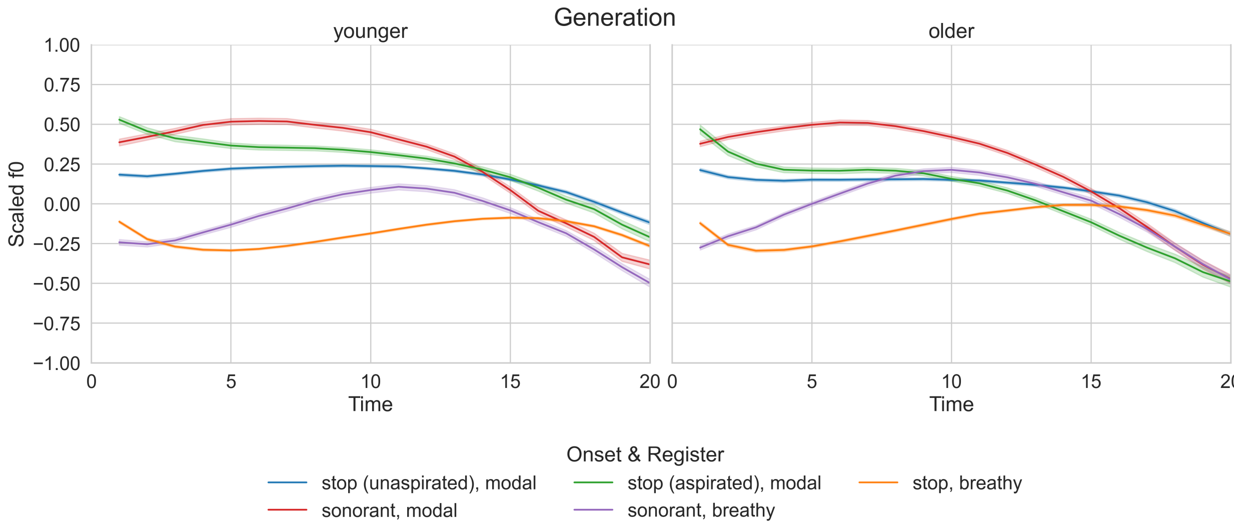


Figure 3.7: f0 by consonant type and voice quality

representative.

Figure 3.8 looks at coda effects on (scaled) f0 values, taking into account voice quality. These effects may be compared with the findings by Sukkasame (2004) of incipient tonal contours in two Kuay varieties, summarized again in Table 3.7 (and mentioned in §1.2). Sukgasame finds 6 tonal patterns that are conditioned by register and rhyme. Open syllables are those that lack a coda or that have a sonorant coda. In the closed syllables, T stands for a stop coda, which may be preceded by a short (V) or long (V:) vowel. The tones described by Sukgasame are accompanied by Chao numerals to indicate the level and shape of the contours.

The two trajectories that clearly differ by generation are those of modal vowels with a stop coda. When the vowel is short, f0 remains at mid level throughout for the older generation, while it shows a low-rising trajectory for the younger generation. When the vowel is long, f0 shows a low-rising trajectory for older speakers, but a mid-rising one for younger speakers. The tone contours that match Sukgasame's findings are the ones for open syllables, breathy /-h/ and /-VT/, and modal /-ʔ/ and /-V:T/ (for younger speakers). Modal /-h/ and /-VT/ show a mid-level tone, while breathy /-ʔ/ and /-V:T/ show a low rising tone that ends high.

What is particularly striking is that the younger generation has virtually fully overlapping contours for /-h/ and /-VT/ as well as for /-ʔ/ and /-V:T/, showing six tone contours as described in the Kuay varieties observed by Sukgasame.[6] The consolidation of these f0 trajectories suggests that there may be a shift towards stabilization of these tonal patterns. However, as /-h/ and /-V:T/ are each represented by only 2 words each and /-ʔ/ and /-VT/ by only 4 words each, it cannot be yet concluded that these results are meaningful.

[6]While there is a slight drop when the coda is a glottal stop, this may be due to the fact that f0 tracking drops sharply when there is glottalization.

Table 3.7: Tonal contours in Kuay described by Sukkasame (2004, 693–695) (adapted)

	Rhyme or coda type					
Register	open		-h, -VT		-ʔ, -V:T	
Modal	high falling	[451]	high level	[44]	high rising	[45]
Breathy	low rising falling	[121]	low rising	[254]	low level	[22]

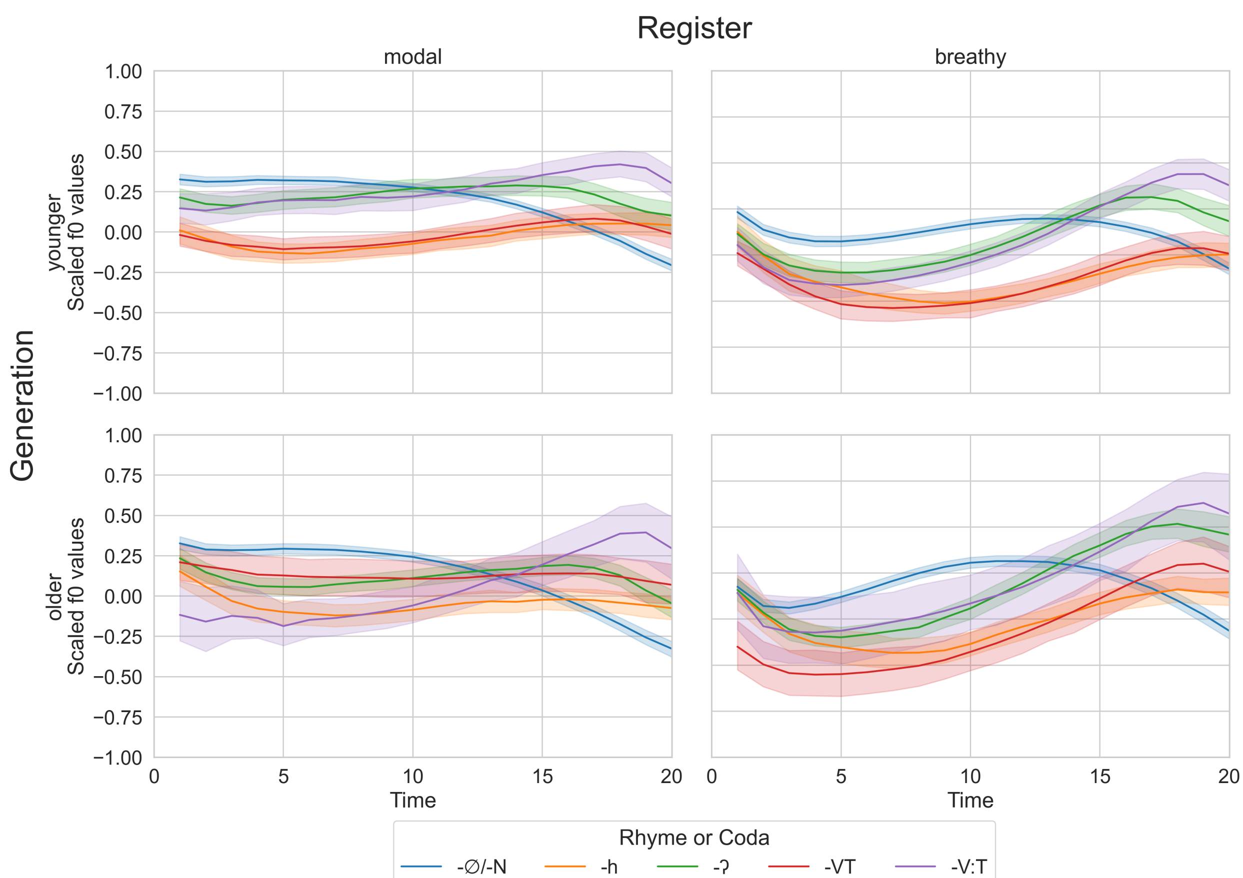


Figure 3.8: f0 by voice quality and rhyme

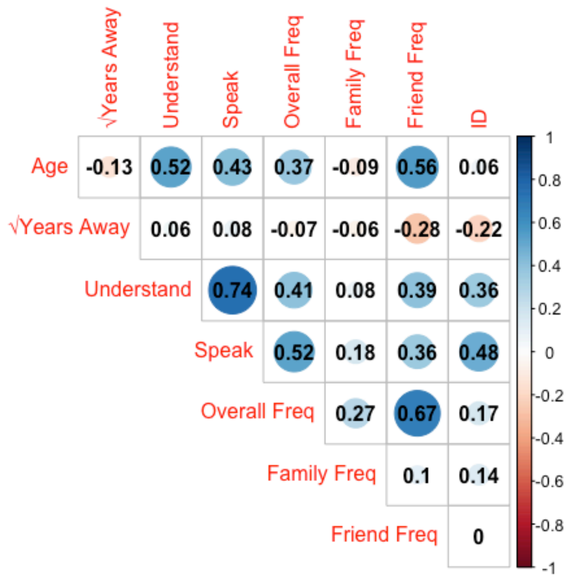


Figure 3.9: Correlation matrix for social factors

PCA results

PCA on social variables

Correlations between the social variables are shown in Figure 3.9 and the scree plot showing the percentage of variance explained by each dimension is shown in Figure 3.10. The first dimension captures 39.51% of the variance and, as can be seen in Figure 3.11, is primarily contributed to by most of the sociolinguistic variables except for frequency of Kuy usage with one's own family, identity, 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 correlation of each factor to each of the dimensions may be seen in Table 3.8. 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 we are also interested in the effect of time spent living in non-Kuy speaking areas, the factor $\sqrt{}$Years Away will be employed in the analysis and will be referred to as simply as *Time Away*. The Pearson correlation between TLE and Time Away is insignificant (r = -.16, p = .2), so these variables may be treated independently of one another. An independent t-test also reveals that there are no significant gender differences for either TLE (t = 0.4, p = .64) or Time Away (t = -1.07, p = .29).

Table 3.8: Correlation of social factors to each dimension in production PCA

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Age	0.69	-0.39	0.27	-0.21	0.36	0.35	-0.05	-0.05
√Years Away	-0.16	0.34	0.74	0.50	-0.10	0.17	0.14	0.05
Understand	0.80	0.24	0.29	-0.10	0.21	-0.33	0.15	-0.19
Speak	0.82	0.38	0.17	-0.01	-0.03	-0.09	-0.29	0.24
Overall Frequency	0.76	-0.16	-0.13	0.36	-0.41	0.07	-0.12	-0.23
Family Frequency	0.23	0.31	-0.57	0.62	0.37	0.06	0.03	0.01
Friend Frequency	0.73	-0.54	-0.12	0.12	-0.14	-0.06	0.25	0.23
ID	0.42	0.64	-0.30	-0.45	-0.19	0.23	0.18	0.00

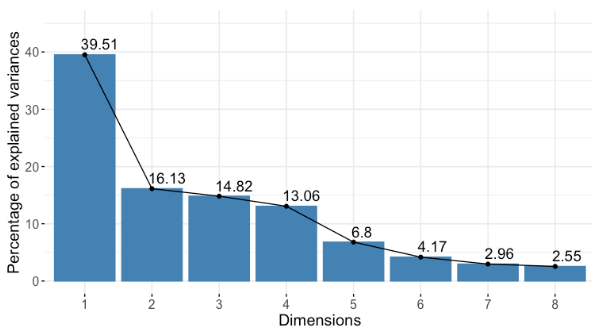


Figure 3.10: Scree plot for PCA on social variables

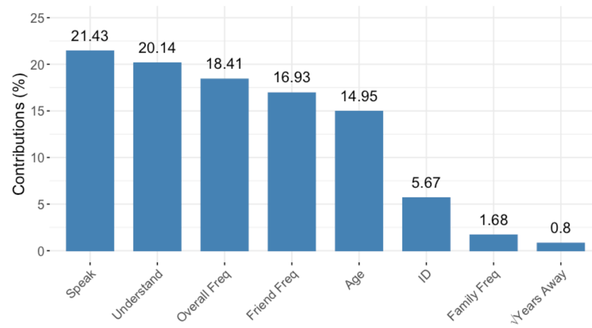


Figure 3.11: Social variable contributions to Dimension 1

PCA on acoustic correlates of voice quality

Correlations between the voice quality variables are shown in Figure 3.12 and the percentage of variance explained by each dimension in the PCA for the voice quality variables is shown in Figure 3.13. Dimension 1 captures 41.86% of the variance; the contribution of each voice quality factor is presented in Figure 3.14, demonstrating that it 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. The correlations of each voice quality measure to each dimension are shown in Table 3.9

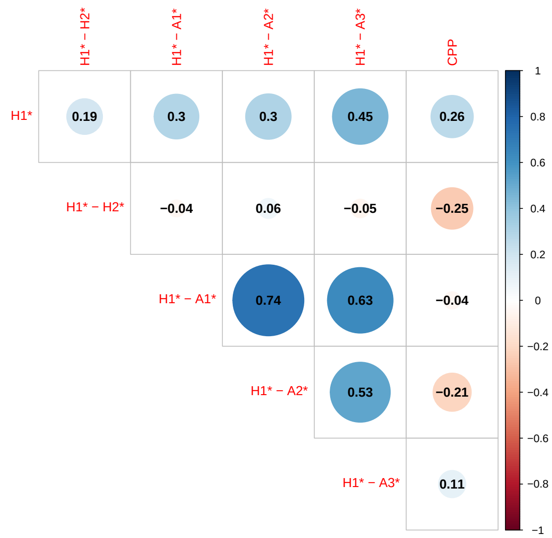


Figure 3.12: Correlation matrix for voice quality variables

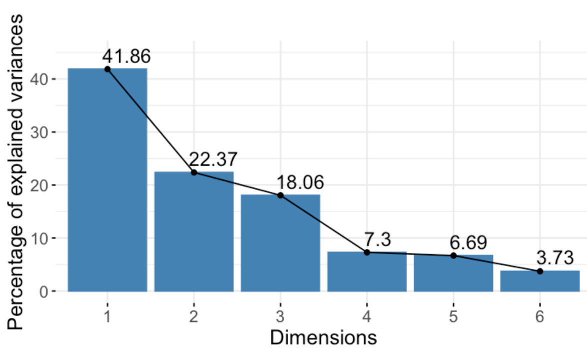


Figure 3.13: Scree plot for PCA on VQ measures

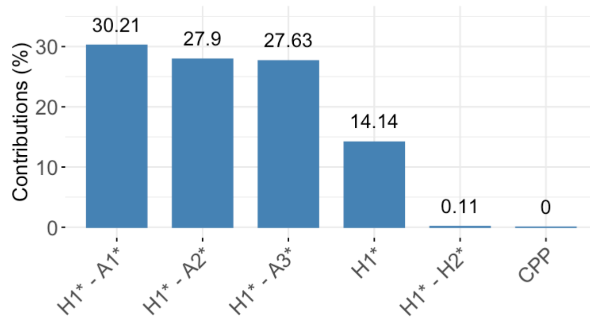


Figure 3.14: VQ measure contributions to Dimension 1

Linear Model Results

The linear model regression analyses show a 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). For 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

Table 3.9: Contributions of VQ measures to each dimension

Dimension	1	2	3	4	5	6
% of Explained Variances	39.33	22.79	17.94	7.89	7.53	4.51
H_1*	15.9	15.34	17.97	1.44	44.80	4.56
H_1*-H_2*	0.72	8.87	72.43	3.52	14.46	0.00
H_1*-A_1*	29.91	1.30	7.31	10.00	6.06	45.43
H_1*-A_2*	26.65	10.30	2.12	15.59	5.92	39.42
H_1*-A_3*	26.80	4.19	0.12	42.84	19.59	6.46
CPP	0.01	60.00	0.05	26.62	9.17	4.15

Time 1, $p < .001$ at Time 3). For 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.

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 with the `effects` package in R (Fox and Hong, 2009), using the results of the linear models. In order for readers to grasp the magnitudes of the differences, the estimated scaled values were converted back to the original Hertz units 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. The resulting semitones are then converted to Hz. These values are visualized in Figures 3.15 through 3.19. 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 3.10 quantifies the mean difference between modal and breathy trajectories for each measure in Figures 3.15 through 3.19. These mean differences will be referred to as F for female participants and M for male participants. Note that these models were also run with words with sonorants and aspirates (and their associated breathy counterpart) in order to account for the observations in §3.2 that the f0 trajectories of vowels following sonorants and aspirates look different from those following unaspirated voiceless stops. However, the results changed little, likely due to the low word count. Future studies should probe the behavior of register with respect to sonorants and aspirates in greater detail.

Differences will be discussed for each measure in turn. Figures 3.15 through 3.17 may each be thought of as representing eight theoretical speakers (four women and four men) who would have a TLE score 1.5 standard deviations below (the "less TLE" row) or above (the "greater TLE"

[7] The 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 (and they may be transitional effects due to being timepoints at vowel boundaries), they will not be discussed.

Table 3.10: 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		**Male**	
			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	”
		↓TLE	40.17 Hz	”	39.34 Hz	”
	low	**↑TLE**	88.61 Hz	”	31.43 Hz	”
		↓TLE	75.87 Hz	”	57.11 Hz	”

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 use 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 3.18 and 3.19, the bottom row shows theoretical speakers who would be “more conservative” than the top one. 95% confidence intervals are included for each trajectory.

For both female and male speakers, less 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

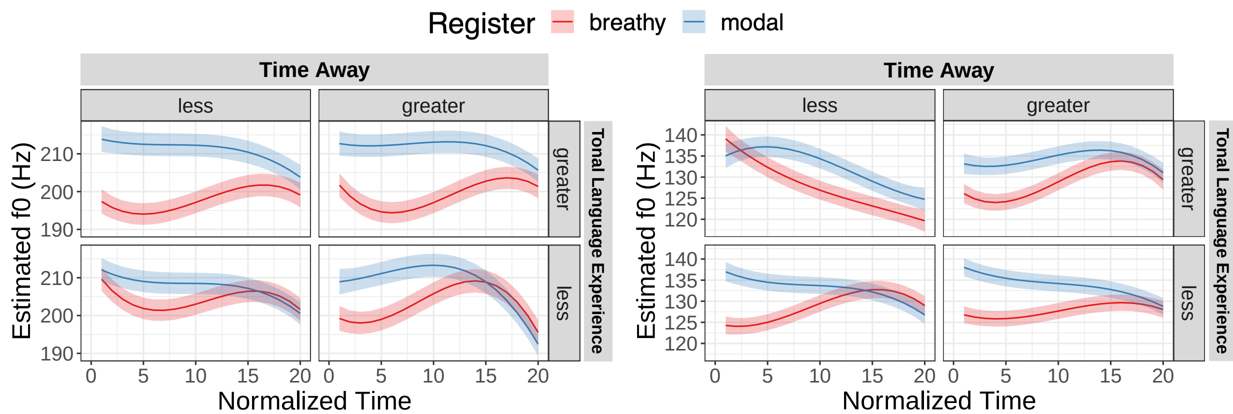


Figure 3.15: Estimated f0 trajectories for female (left) and male (right) speakers

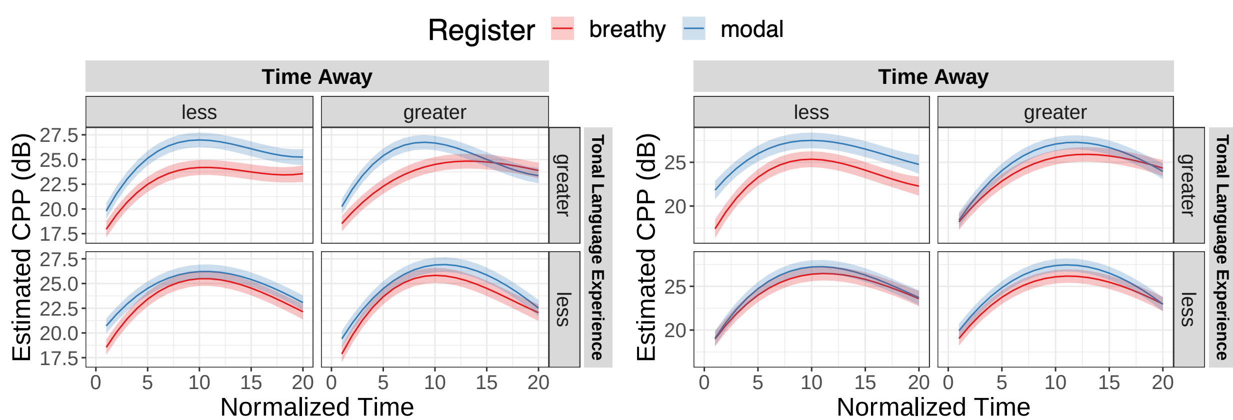


Figure 3.16: Estimated CPP trajectories for female (left) and male (right) speakers

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.

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.

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

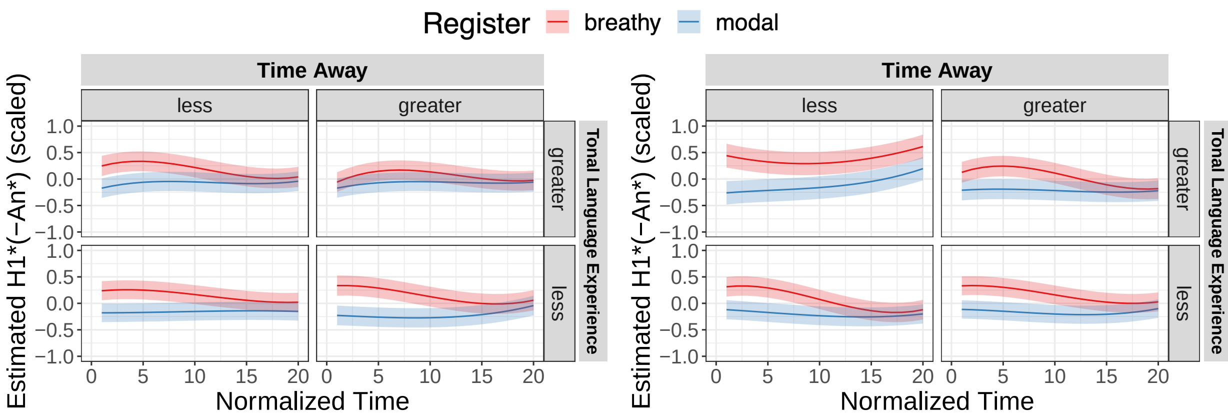


Figure 3.17: Estimated H_1*(-A_n*) trajectories for female (left) and male (right) speakers

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.

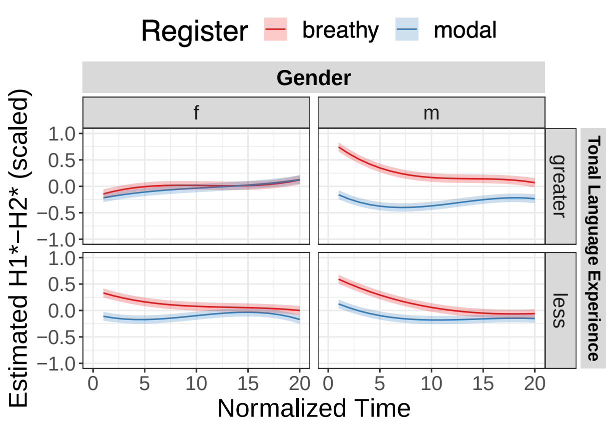


Figure 3.18: Estimated H_1*-H_2* trajectories

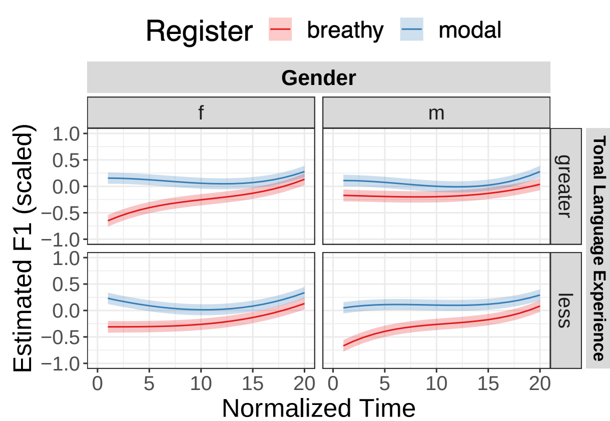


Figure 3.19: Estimated F1 trajectories

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).

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. The positive correlation of TLE with f0 differences for female speakers corroborates the hypothesis. The effect of Time Away on increasing f0 differences appears modest at best.

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 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. Contrary to the hypothesis, TLE is correlated with greater H_1*-H_2* differences for male speakers and greater CPP differences for female speakers.

Individual differences

The accuracy scores of the LDA classifier for each of the five acoustic measures (f0, 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 3.11 shows the mean and standard deviations of the accuracy scores, subgrouped by gender, for each cue. Overall, F1 and VQ are stronger cues for the register distinction in production than f0 is. However, each of the individual voice quality cues themselves (H_1*-H_2*, H_1*(-A_n*), and CPP) are weaker cues than f0 is, for female speakers. For male speakers, however, H_1*(-A_n*) is equal to f0 in importance, while H_1*-H_2* is a stronger cue. From this data, it is clear that register is *not* primarily cued by f0 in the *overall* population.

Table 3.12 enumerates the number of speakers for whom each cue is strongest, split by TLE (less TLE: < 0, more TLE: ≥ 0), while 3.13 also includes the combined VQ measure. With the VQ

Table 3.11: Mean and standard deviations of accuracy scores in production, subgrouped by gender

	F		M	
	Mean	SD	Mean	SD
f0	.64	.13	.62	.1
H_1*-H_2*	.54	.12	.69	.15
H_1*(-A_n*)	.57	.1	.62	.09
CPP	.6	.1	.56	.12
F1	.74	.08	.69	.11
VQ	.73	.12	.79	.11

Table 3.12: Register cue with highest weight (excluding combined VQ measure) by number of speakers, split by TLE

	F		M	
Cue	Less TLE	More TLE	Less TLE	More TLE
f0	1	7	2	2
H_1*-H_2*	2	0	2	10
H_1*(-A_n*)	3	0	1	1
CPP	0	1	0	1
F1	10	9	11	2

cues split up as in Table 3.12, we can see that the most important cue for female speakers is F1 but is H_1*-H_2* for male speakers with greater TLE. The number of female speakers for which f0 is the most important cue jumps from 1 in those with less TLE to 7 in those with greater TLE. Table 3.13 shows that all the VQ cues combined are more informative than f0 and F1 for just over half of the speakers (34 out of 66). F1 is the strongest cue for the plurality of female speakers with greater TLE. It is also notable that f0 is the strongest cue for four speakers with greater TLE as opposed to one speaker with less TLE.

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 3.14. Scatterplots

Table 3.13: Register cue with highest weight (including combined VQ measure) by number of speakers, split by TLE

	F		M	
Cue	Less TLE	More TLE	Less TLE	More TLE
f0	1	4	1	1
H_1*-H_2*	0	0	1	3
VQ	8	6	9	11
F1	7	8	5	1

Table 3.14: Correlations between LDA accuracy of acoustic cue and TLE

	F			M		
Measure	r	p	Sig.[8]	r	p	Sig.
f0	.44	.009	**	-.02	.93	
H_1*-H_2*	-.2	.26		.42	.02	*
H_1*(-A_n*)	-.28	.11		.09	.63	
CPP	.42	.01	*	.28	.13	
F1	.14	.44		-.45	.01	*
VQ	-.17	.34		.31	.09	

of the significant correlations with TLE, with regression lines and a 95% confidence interval for each gender, are displayed in Figure 3.20. TLE is significantly positively correlated with f0 ($r = .44, p < .01$) and CPP ($r = .42, p < .05$) accuracy for female speakers. For male speakers, TLE is significantly positively correlated with H_1*-H_2* ($r = .42, p < .05$), but negatively correlated with F1 ($r = -.45, p < .05$) accuracy.

To test (2), Pearson's r was first calculated between f0 and each voice quality cue, the results of which are presented in Table 3.15. The only significant relationships are a negative correlation between f0 and H_1*-H_2* ($r = -.36, p < .05$) and between f0 and VQ ($r = -.41, p < .05$) for female speakers. All correlations are visualized in Figure 3.21, with a thick black line and surrounding grey shaded region representing the regression line and a 95% confidence interval for the two significant correlations. 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 striking 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.

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

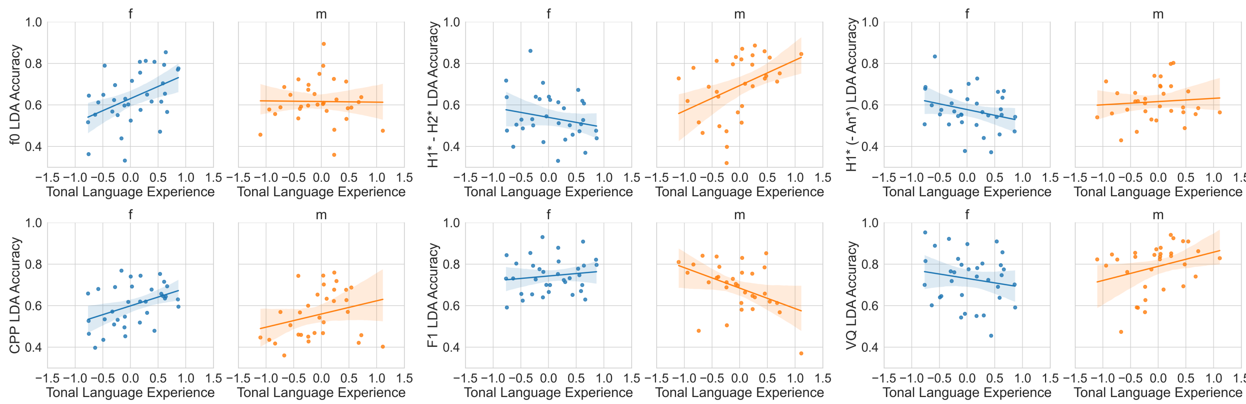


Figure 3.20: Correlation of LDA Accuracy of each acoustic measure to TLE

Table 3.15: Correlations between f0 and each voice quality cue

	F			M		
Comparison	r	p	Sig.	r	p	Sig.
f0 : H_1*-H_2*	-.36	.04	*	-.21	.25	
f0 : H_1*(-A_n*)	-.17	.35		.15	.41	
f0 : CPP	-.07	.69		.03	.88	
f0 : F1	-.02	.89		.2	.28	
f0 : VQ	-.41	.02	*	.05	.77	

Pearson's r was also calculated between F1 and each voice quality cue, but no correlations were significant, demonstrating no tradeoff between F1 and other cues.

The individual results provide evidence supporting the second hypothesis and half of the first hypothesis, but only for female speakers, who show f0 as an increasingly reliable cue for register with greater usage of a tonal language and a tradeoff between f0 and H_1*-H_2* as well as between f0 and the combined voice quality measure. Interestingly, female speakers with more tonal language experience also show CPP as an increasingly reliable cue for register. It is also important to note that F1 is a very reliable cue for female speakers regardless of TLE. Male speakers, on the other hand, do not behave as hypothesized. Greater TLE for male speakers unexpectedly *increases* H_1*-H_2* weights. Interestingly, it also weakens F1 cue weights. Neither group shows any significant relationships with Time Away on the individual level.

3.3 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

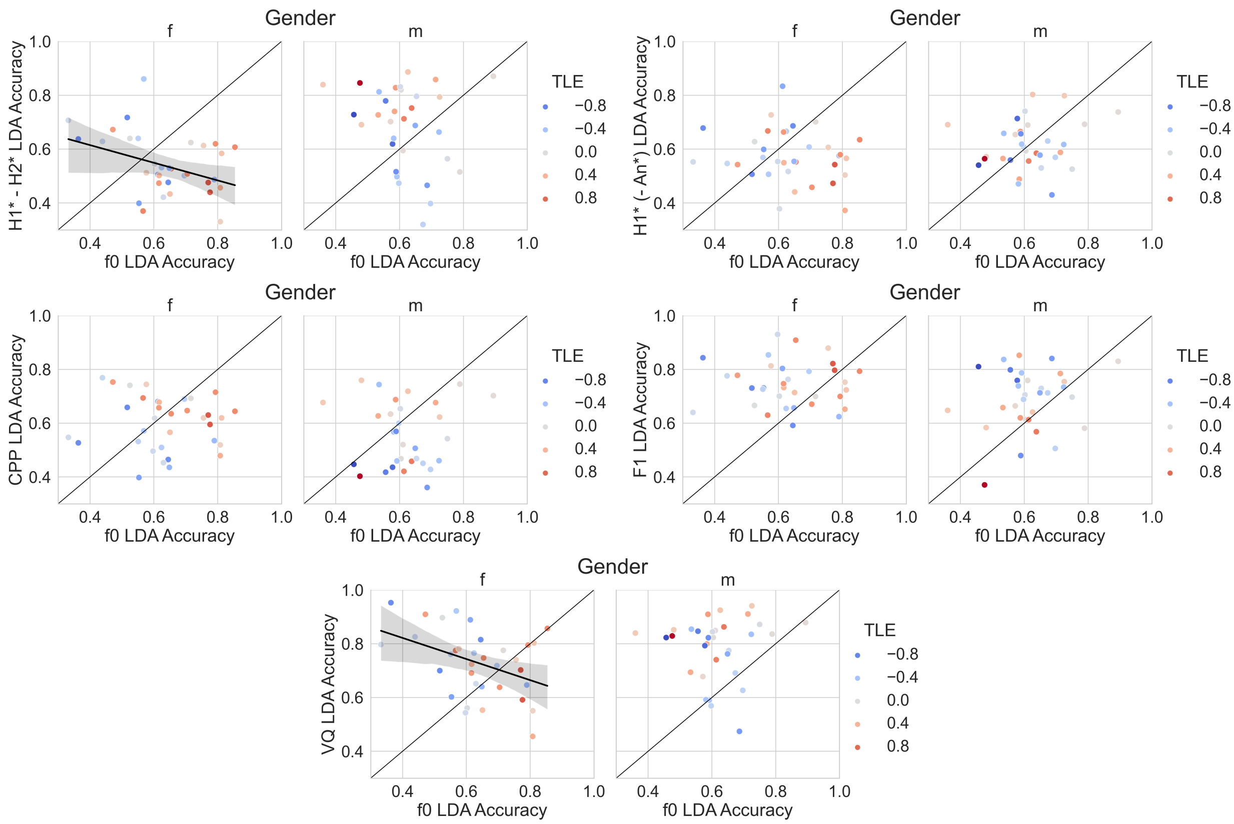


Figure 3.21: Correlation of LDA Accuracy of each acoustic measure to TLE

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.

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* 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 female speaker. Tonal language experience does not appear to have any significant effect on f0 for male speakers at either the group or individual level, contrary to the hypothesis. The two relationships that do appear to hold on both the group and individual levels are the decreased weighting of F1 and the unexpected increase in H_1*-H_2* weighting with more tonal language usage.

Time away and the register contrast

Time spent away from home interestingly appears to have little effect on the register contrast at both the group and individual levels. 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. It could also be the case it is the *social circles* of these speakers while they are away from home that is relevant. One's occupation while away from home also influences one's social circles. 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.

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. 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, as mentioned in §1.2. 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 tended to report being salespeople while living in other areas. 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 less dense 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. These patterns are particularly reminiscent of a study of language change in Belfast by Milroy and Milroy (1985), in which they found that speakers in strong, close-knit networks within the community were more conservative in their realizations of /a/ and /ɛ/, while those whose ties are weaker and who have looser networks (that is, they interact with people from different networks) were more innovative. Other related literature on network strength and innovation include Bortoni-Ricardo (1985); Eckert (2000); Fox et al. (2011), and Sharma and Dodsworth (2020). Because of the nature of their occupations, particularly while living outside of the Kuy village, women likely use more Thai in a variety of contexts due to the various people with which they would come in contact, mirroring the looser networks of the Belfast innovators. The innovation in this situation is the increased f0 differences seen in their speech.

3.4 Summary

A key finding of the production experiment is the increased differences in f0 between the registers in Kuy for female speakers who have more experience with Thai and Lao, both of which are tonal languages, but not for male speakers. With regards to voice quality, female speakers and male speakers actually show an increase in usage of voice quality in the form of greater CPP and H_1*-H_2* differences with more tonal language experience, respectively (although CPP is the strongest cue for only one female speaker and one male speaker, each). F1 differences decrease as well for male speakers with more tonal language experience. F1 is a robust cue for male speakers with less tonal language experience and for female speakers overall, although its reliability decreases with tonal language experience. In terms of cue tradeoff, female speakers show a tradeoff between f0 and voice quality in the form of both H_1*-H_2* and the combined voice quality measure.

Thus, while female speakers show an effect of tonal language experience aligning with most of the hypotheses, there is little evidence of a unified effect of tonal language experience for male speakers and voice quality actually appears to be a *stronger* cue for male speakers with greater tonal language experience. The results of the production experiment with respect to the hypotheses may be summarized as follows:

1. Greater usage of the tonal languages Thai and Lao, relative to the non-tonal languages Kuy and Khmer, will lead to increased f0 differences in the Kuy register contrast
   - ⋆ Hypothesis is supported for female speakers
   - ⋆ Hypothesis is not supported for male speakers
2. Greater usage of the tonal languages Thai and Lao, relative to the non-tonal languages Kuy and Khmer, will lead to decreased voice quality differences in the Kuy register contrast
   - ⋆ Hypothesis is unsupported for female speakers
     - ◦ CPP differences actually increase with greater TLE
   - ⋆ Hypothesis is unsupported for male speakers
     - ◦ H_1*-H_2* differences actually increase with greater TLE
     - ◦ F1 differences, however, decrease with greater TLE
3. There is a tradeoff between f0 and other register cues
   - ⋆ Hypothesis is supported for female speakers
     - ◦ There is a tradeoff between f0 and H_1*-H_2*
     - ◦ There is a tradeoff between f0 and voice quality overall
   - ⋆ Hypothesis is unsupported for male speakers

Chapter 4

Experiment 2: Kuy Register in Perception

The second study, carried out in 2019, assessed the extent to which Kuy speakers attend to voice quality and f0 cues in perception of the register contrast. §4.1 details methodology that is specific to the perception experiment and explains how the methodology common to both experiments was applied. §4.2 lays out the results of the perception experiment. The results are then interpreted in §4.3 and the findings are summarized in §4.4.

4.1 Methodology

Participants

74 participants in total were recruited with the help of Thongwilai Intanai to partake in the perception experiment. However, 10 participants were excluded from the final analysis for failing to complete the experiment, performing at chance or with an 87.5% or higher bias in response, recording issues, and failing to meet demographic requirements (i.e. were in the wrong age range or fit into an age-gender combination that was already fulfilled). The remaining 64 participants were perfectly balanced for age and gender—these demographics are presented in Table 4.1. 36 of these participants are from Ban Khi Nak, 13 from Ban Khi Nak Noi, and 13 from Ban Rong Ra, the three villages represented in the production study. Of the remaining 2 speakers, 1 was from Ban Phlong and 1 from Ban Huay Khong.

As in the production study, all speakers are minimally bilingual in Kuy and Thai and understand Lao. 3 speakers report not understanding Khmer. 4 speakers report being unable to

Table 4.1: Participants in perception experiment

	20s	30s	50s	60s
F	8	8	8	8
M	8	8	8	8

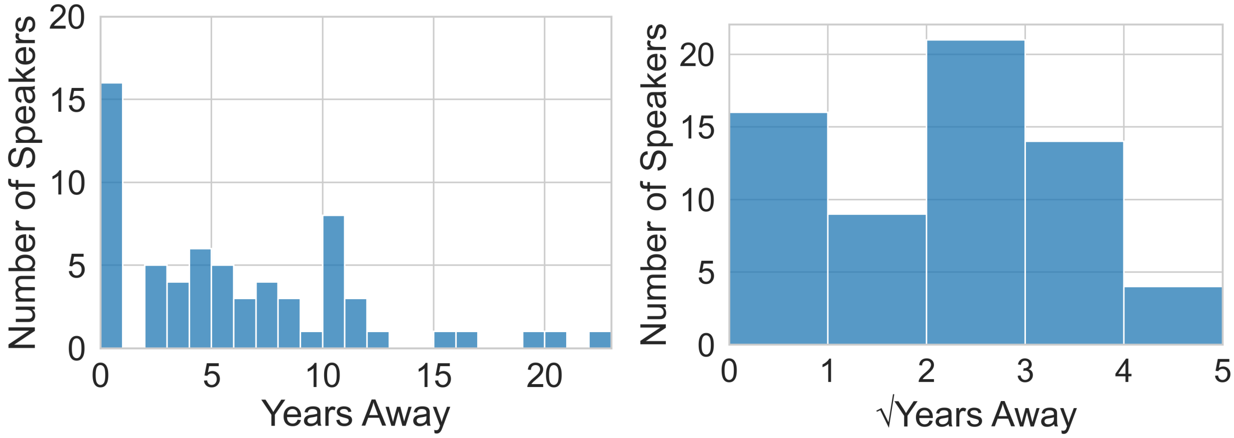


Figure 4.1: Histograms of time spent away by participants (left: raw; right: square-rooted)

speak Lao, while 11 report being unable to speak Khmer. 16 have never spent time outside of a Kuy-speaking area. The distribution of time spent away from home (measured in years) may be seen in the left graph of Figure 4.1. The mean and median time spent away are 5.76 and 5 years, respectively, while the minimum (non-zero value) and maximum number of years spent away are 2 and 23 years, respectively. Due to the right skew (1.07), the number of years spent away was square rooted for analysis. The distribution of $\sqrt{}$Years Away can be seen in the right graph of Figure 4.1 (mean: 1.98, median: 2.24, skew: -0.21). As with the production study, there is significant variation in the remaining sociolinguistic variables that will be probed in this study.

Stimuli

The stimuli for the perception study were based off two minimal pairs: (1) /tiː/ 'old' vs. /ti̤ː/ 'tall' and (2) /taʔ/ 'to grab' and /ta̤ʔ/ 'to place under'. These were chosen as they were the most consistently produced minimal pairs in the production study. For each minimal pair, a continuum was created, using the KlaatGrid synthesizer (Weenink, 2009) through a Praat script adapted from Brunelle et al. (2020) between the modal and breathy members by varying two parameters: f0 and open quotient (OQ), for the first half of the vowel. OQ, the proportion of the glottal cycle for which the vocal folds are apart, is an articulatory correlate of voice quality and correlates with H_1*-H_2* (Holmberg et al., 1995; Henrich et al., 2001). Higher OQ values correspond to breathier phonation. Each continuum consisted of 5 beginning f0 values ranging from 110 to 140 Hz crossed with 5 beginning OQ values ranging from 30% to 70%, spaced evenly, yielding 25 tokens for each minimal pair. This is schematized in Figure 4.2. F1 trajectories were synthesized to be intermediate between the two registers as F1 was not the focus of the study, and to keep the experiment from being too lengthy. The 50% OQ tokens were synthesized such that the H_1*-H_2* trajectories lay between the average H_1*-H_2* trajectories of the modal and breathy members of each minimal pair in a 61-year old male speaker with a clear H_1*-H_2* distinction, and the 50%

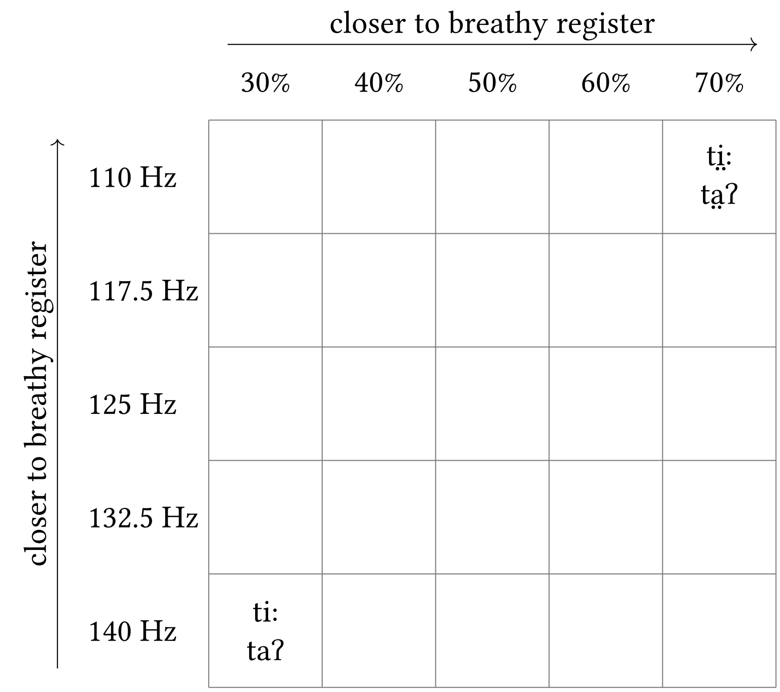


Figure 4.2: Stimuli for perception experiment, with modal and breathy endpoints marked

f0 tokens such that the f0 trajectories lay between the average f0 trajectories of the modal and breathy members of each minimal pair in a 24-year old male speaker with a clear f0 distinction. Due to the stimuli for the perceptual experiment being limited to male voices, it is important to note that there is a potential for bias in the results and that this is a limitation of the experiment design. Italicization of *ti:* and *taʔ* (without indicating register) will be used to refer to the two minimal pairs; if register is relevant, phonemic representation between slashes will be used to differentiate.

Procedure

For the perception study, participants were tasked with listening to stimuli and identifying which member of the minimal pair they heard. The identification task took the form of a 2-alternative forced choice task—after hearing the stimulus, participants had to choose one of two images, each corresponding to a member of a minimal pair. Following a practice block for each minimal pair in which I walked participants through the task, participants then underwent 16 blocks, alternating between a *ti:* block and a *taʔ* block, with optional breaks in between. The 25 stimuli in each block were randomized and presented with 500 ms interstimuli intervals. Participants were allowed a maximum of 5000 ms to respond to a given stimulus; if they did not, a non-response was recorded. Excluding the practice rounds, participants listened to a total of 400 tokens. The task took approximately 15 to 30 minutes, depending on the speed at which the participant carried

Figure 4.3: Images seen on screen
(left: *ti:* block: /ti:/ ‘old’ vs. /ti̤:/ ‘tall’; right: *taʔ* block: /taʔ/ ‘to grab’ vs. /ta̤ʔ/ ‘to place under’)

out the task.

How these images appeared on the screen to participants may be seen in Figure 4.3. The experiment was presented in OpenSesame (Mathôt et al., 2012) on a Microsoft Surface Go tablet and participants used AKG K240 Studio Headphones. As participants were unfamiliar with experimental tasks (other than those who had partook in the production experiment), the task was made as simple as possible in two ways: first, the images were presented on a touchscreen, as participants were familiar with using touchscreens on their phones, and participants used a stylus to swipe the picture representing the word they heard. Second, no text was used as Kuy orthography is not standardized, as well as to avoid the potential interference of Thai writing on participants’ choices.

2 conditions were toggled to handle ordering effects: (1) whether *ti:* or *taʔ* came first and (2) the orientation of the pictures of the minimal pair, yielding 8 conditions in total. Since there were 8 participants of each gender in each age group, each participant in a given age-gender combination was assigned to a different ordering condition. Finally, in order to account for left-right bias, the position of the images was swapped in each consecutive block of a given syllable. The layout of the 8 conditions are summarized in 4.2

Following the perception experiment, I administered to participants the same sociolinguistic questionnaire as used in the production experiment to determine social factors related to language usage and ethnolinguistic identity. Finally, I carried out an approximately 10-minute unstructured sociolinguistic interview with the participant to understand better the participants’ life experiences, as well as to help gauge language attitudes across the Kuy community.

Table 4.2: Conditions to account for ordering effects

Condition	Round 1, Pair 1		Round 1, Pair 2		Round 2, Pair 1		Round 2, Pair 2		…
	Left	Right	Left	Right	Left	Right	Left	Right	…
1	/tiː/	/ti̤/	/taʔ/	/ta̤ʔ/	/ti̤ː/	/tiː/	/ta̤ʔ/	/taʔ/	…
2	/tiː/	/ti̤/	/ta̤ʔ/	/taʔ/	/ti̤ː/	/tiː/	/taʔ/	/ta̤ʔ/	…
3	/ti̤ː/	/tiː/	/taʔ/	/ta̤ʔ/	/tiː/	/ti̤/	/ta̤ʔ/	/taʔ/	…
4	/ti̤ː/	/tiː/	/ta̤ʔ/	/taʔ/	/tiː/	/ti̤/	/taʔ/	/ta̤ʔ/	…
5	/taʔ/	/ta̤ʔ/	/tiː/	/ti̤/	/ta̤ʔ/	/taʔ/	/ti̤ː/	/tiː/	…
6	/taʔ/	/ta̤ʔ/	/ti̤ː/	/tiː/	/ta̤ʔ/	/taʔ/	/tiː/	/ti̤/	…
7	/ta̤ʔ/	/taʔ/	/tiː/	/ti̤/	/taʔ/	/ta̤ʔ/	/ti̤ː/	/tiː/	…
8	/ta̤ʔ/	/taʔ/	/ti̤ː/	/tiː/	/taʔ/	/ta̤ʔ/	/tiː/	/ti̤/	…

Analytical methods

Logistic regression

As in the production experiment, a PCA was employed, using the `FactoMineR` package (Lê et al., 2008) in R (R Core Team, 2018) to reduce the highly correlated social variables. The same measures, scaled with the method from Gelman (2008), were input into the PCA. To explore group differences, a logistic mixed effects regression model was fitted using the `lme4` package, also in R, looking at the effect of the interaction of Gender, OQ, f0, and Tonal Language Experience (TLE, the first principal component from the PCA) on the binary Register response. OQ, f0, and TLE were all scaled with Gelman's method. The maximal model for each measure yielded the lowest AIC, so all interactions were kept. Random intercepts were included for Speaker and Syllable (*ti:* vs. *taʔ*), but random slopes were not included as they led to overfitting. Model predictions were calculated using the `effects` package in R (Fox and Hong, 2009).

Linear discriminant analysis (LDA)

Individual differences were then explored by quantifying cue weights for f0 and OQ through the use of LDA through the `scikit-learn` package in Python (Pedregosa et al., 2011), as in the production experiment. The input for the LDA was the f0 and OQ values for each token, and the categories were the register of the token, as labeled by the participant. The training and test processes utilized 10-fold cross validation, with the mean of the 10 results being used as the proxy for the cue weight of f0 and OQ. Pearson's r was calculated between these cue weights and TLE to test whether there was a correlation between these sociolinguistic factors and perception cue weights. The correlation between f0 and OQ was also calculated to see if there was a tradeoff.

The input features for the model were *f0* and *open quotient*, to stand in as a proxy for voice quality. 2 LDAs were run for each of the 64 participants in the study: one using f0 features and one using open quotient features (to be called the *f0 model* and the *voice quality model*). 10-fold

Table 4.3: Hypotheses for results of LDA

	Cue	↓TLE	↑TLE
Logistic regression	f0	↓influence on decision function	↑influence on decision function
	OQ	↑influence on decision function	↓influence on decision function
LDA	f0	↓accuracy	↑accuracy
	OQ	↑accuracy	↓accuracy
Contrast		↑OQ, ↓f0 usage	↑f0, ↓VQ usage

cross-validation was used in training and the mean accuracy of the f0 and voice quality models were obtained for each participant at the end of the test phase. For a given participant, a high accuracy for voice quality model would suggest that voice quality is the primary cue in perception of the Kuy breathy vs. modal contrast, whereas a high accuracy for the f0 model would suggest that the contrast may be becoming one of tone.

Hypotheses

Because Thai is a tonal language that does not use voice quality, I hypothesize that Kuy speakers who use tonal languages more will show a greater effect of f0 on determining the register of stimuli but a smaller effect of OQ and will show higher accuracy scores for the f0 LDA model but lower accuracy scores for the voice quality LDA model than Kuy speakers who use tonal languages less. These hypotheses are summarized in Table 4.3.

4.2 Results

Summary statistics

The 64 participants listened to a total of 25,600 stimuli. 72 of these stimuli did not have a response, meaning that listeners timed out on them. 25,528 responses were left to be analyzed. 53.8% of responses were “breathy”, while 46.1% were “modal”, suggesting that the acoustic space was relatively balanced between the breathy and modal registers, with a slight bias towards breathy voice. Figure 4.4 shows the percentage of responses, divided by register, over the 8 rounds of the experiment, with 95% confidence intervals (with each speaker’s average percentage being a data point). As can be seen, in early rounds, there is a bias to identify stimuli as breathy, but as participants proceed through the experiment, they converge towards a more equal distribution of breathy and modal responses. This pattern suggests that there is some normalization of the perception of the acoustic space as participants become accustomed to the stimuli, providing a potential confounding factor to account for in perceptual experiments in general.

Figure 4.5 illustrates response time in milliseconds over the 8 rounds of the experiment, divided by generation (younger being aged 20 to 39 and older being aged 50 to 69), with 95% confidence intervals (with each speaker's average response time being a data point). Response times are slightly slower for the older generation (overall mean: 749 ms) than for the younger one (overall mean: 700 ms), although given the overlapping confidence intervals, the difference does not seem to be significant. Unsurprisingly, the response time lowers over the course of the experiment for both generations, reflecting accustomization to the experiment stimuli.

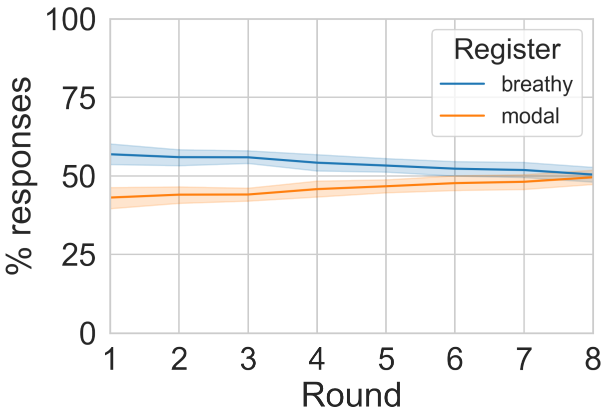


Figure 4.4: Responses by round

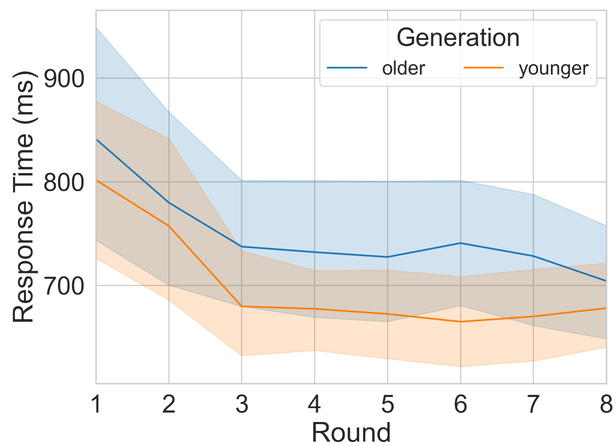


Figure 4.5: Response time by generation

§4.1 described 8 experiment conditions to account for ordering effects. The conditions specified whether the *ti:* or *taʔ* pair is shown first and what the position of the pictures were in the first *ti:* and *taʔ* blocks in the first round. Figure 4.6 shows the percentage of responses, divided by register, over the 8 rounds, with 95% confidence intervals. The top row shows the conditions in which the first block is the *ti:* pair, while the bottom one shows the ones in which the first block is the *taʔ* pair. In the title of each subplot, 1 and 2 may be understood as the first and second blocks, while the order of modal and breathy *ti:* and *taʔ* shows the layout of the modal and breathy images on the screen. For example, in the top left corner, the participant saw the image of /ti:/ 'old' on the left and /ti̤:/ 'tall' on the right in the first block, followed by the image of /taʔ/ 'to grab' on the left and /ta̤ʔ/ 'to place under' on the right. The patterns look mostly the same, with the exception of the second *taʔ* first condition, in which participants were more biased towards modal responses in the first two rounds. While the sample size is only 8 participants per condition, we can tentatively say that ordering effects do not seem to bias responses in a predictable way.

Differences in responses for *ti:* and *taʔ* are shown in Figure 4.7. The OQ of the stimulus is represented by the x-axis, while f0 is represented by color. The y-axis shows the percentage of breathy responses to the stimuli, with 95% confidence intervals. Both syllables show the same expected patterns of more breathy responses for stimuli with greater open quotients and lower f0 values. There does appear to be a difference in the shapes of the response functions, however. Responses for *taʔ* are less influenced by f0 than responses for *ti:* are, as can be seen by the greater distance of the f0 curves from each other in the left graph. The difference in the influence of f0

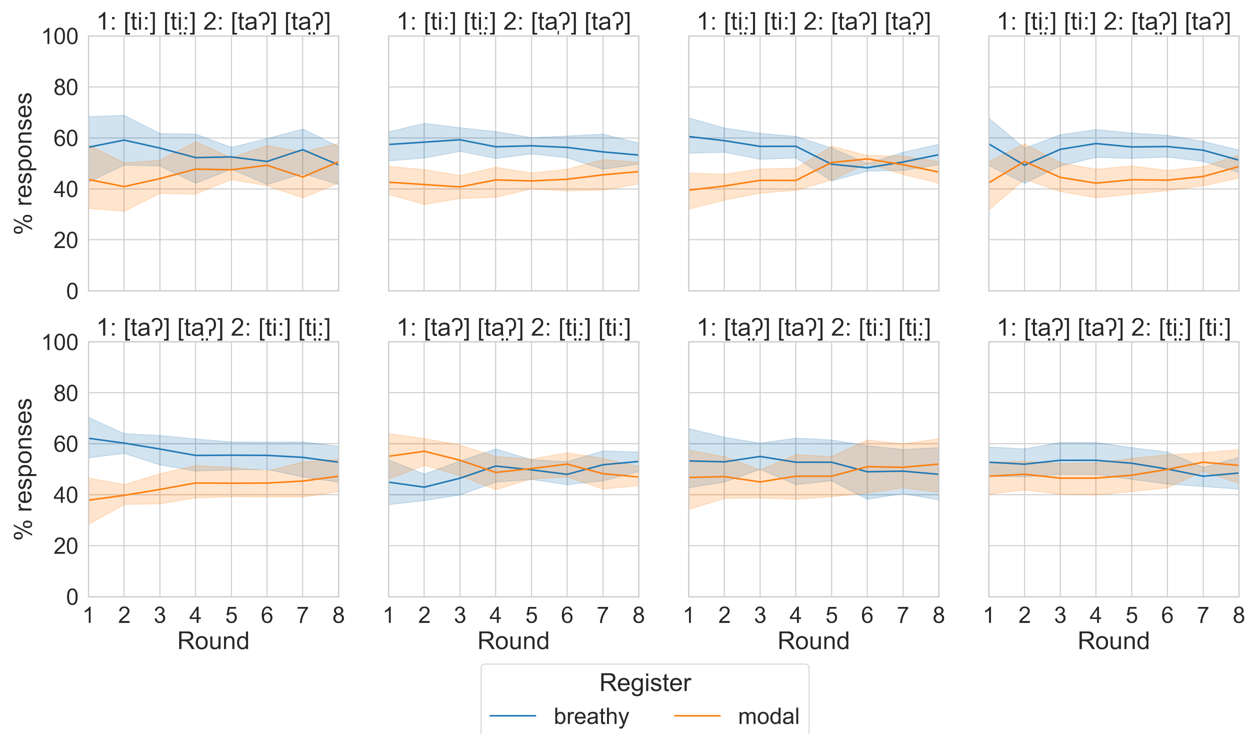


Figure 4.6: Responses by experiment type

is potentially related to the difference in the syllable structure—*ti:* consists of a long vowel with no coda, while *taʔ* consists of a short vowel followed by a glottal stop. As discussed in §1.3, glottal stop codas affect the pitch of a preceding vowel and can also yield a creaky voice quality. Perhaps the inherent influence of the glottal stop on pitch leads to pitch being less of a reliable cue to register in comparison to in an open syllable.

Figure 4.8 is a heatmap illustrating mean response times in milliseconds for each stimulus, split by generation. Longer response times are redder and shorter ones are bluer. The scale of redness and blueness is relative to the generation so that within-group differences can be visualized. The concentration of higher response times for the more ambiguous middle OQ values for both generations is unsurprising, given the importance of OQ in perception of the register difference. A noteworthy difference between generations is the behavior at the extreme modal (30%) and breathy (70%) ends of the OQ continuum. While the older generation has faster response times for stimuli at these endpoints, except when the f0 value is an extreme conflicting value (i.e. low OQ with low f0 and high OQ with high f0), the younger generation shows higher response times even when the f0 values are not as extreme, as can be seen in the redness of the 30% OQ, 117.5 Hz and 30& OQ, 125 Hz squares as well as the 70% OQ, 132.5 Hz square. These differences suggest that the younger generation's response times are more affected by f0 than the older generation's, providing some support for the greater role of the f0 cue in the register distinction.

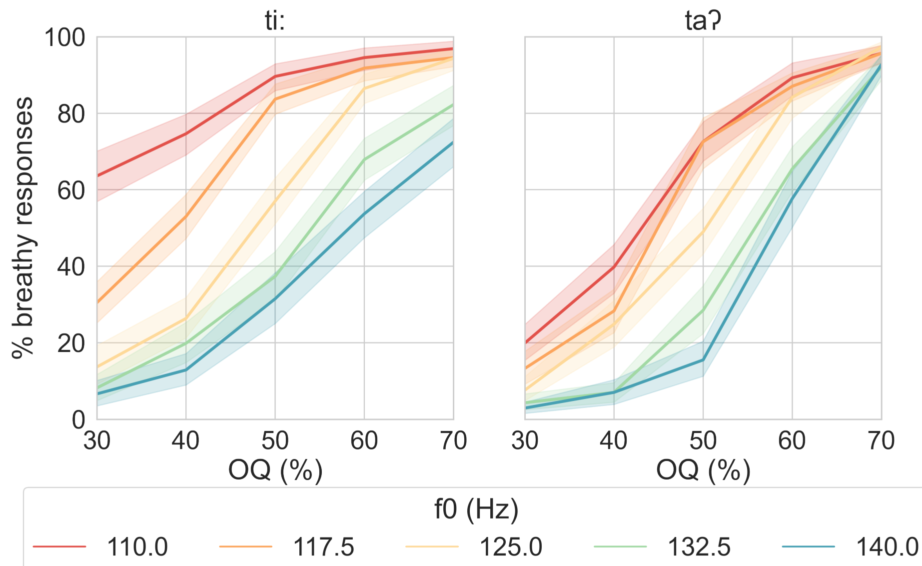


Figure 4.7: Responses by syllable

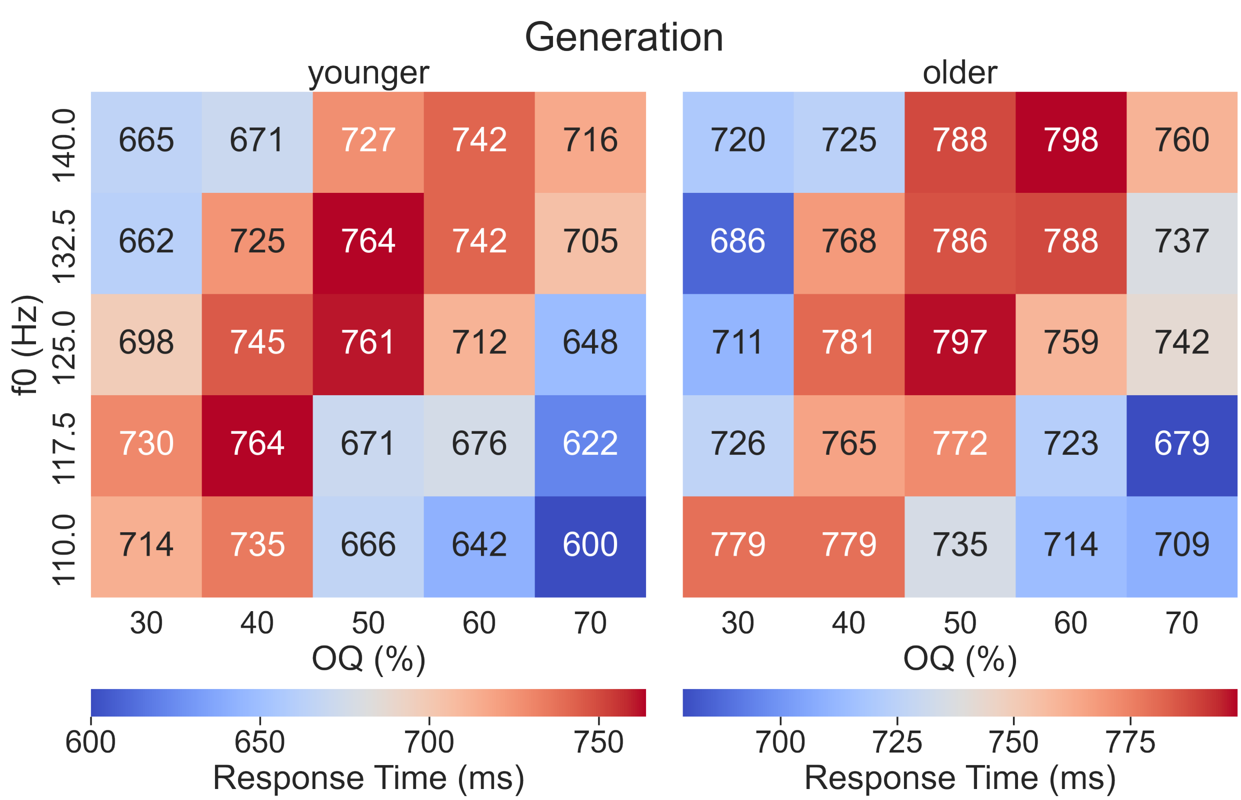


Figure 4.8: Response time by generation

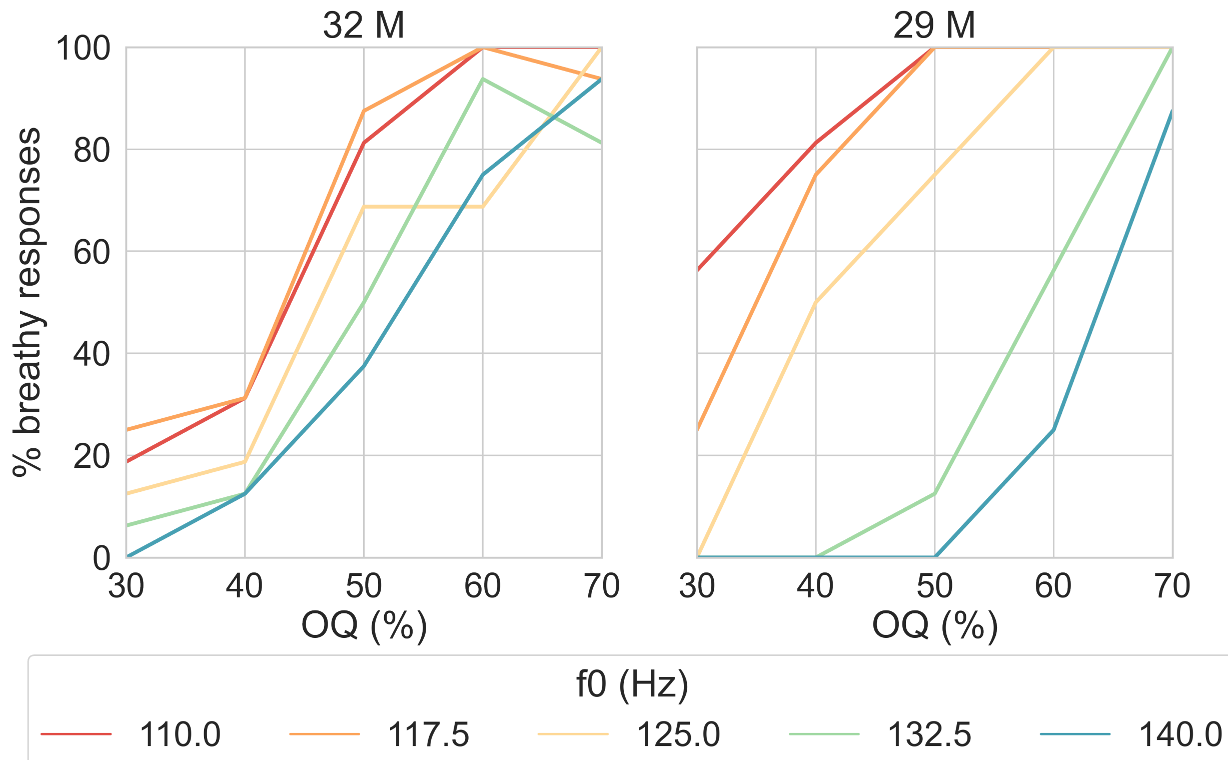


Figure 4.9: Response examples

The analysis of this experiment will focus on analyzing the response patterns of different speakers in the perceptual experiment; that is, how do the combinations of OQ and f0 values affect the proportion of time a stimulus is identified as modal as opposed to breathy? Figure 4.9 provides two illustrative examples: both participants are of a similar demographic—the left participant is a 32-year-old male listener and the right one is a 29-year-old male listener. Despite this, the shape of the response curves is palpably different for these two speakers. The left speaker shows a sigmoid curve for all 5 f0 values that is characteristic of categorical perception: at more extreme OQ values, stimuli are identified as modal or breathy with more certainty, regardless of the f0 value (although there is a slight effect of f0 in the expected direction). At the most ambiguous middle 50% OQ value, the response is much more influenced by f0. The right speaker, on the other hand, shows a more spread-out shape for the response curves: at 50% OQ, the percentage of "breathy" responses ranges from 0% to 100%, depending on the f0 value. Even at 30% OQ, which should sound very "modal", the percentage of "breathy responses" reaches almost 60% if f0 is at the extreme low value of 110 Hz. These patterns provide a basis for understanding of the logistic regression model in the following section: the stronger of an effect f0 has on responses, the more fanned-out and less sigmoidal the response curves, split by f0, should appear.

Table 4.4: Correlation of social factors to each dimension in perception PCA

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Age	0.70	-0.51	0.17	0.17	0.29	0.21	0.22	0.14
√Years Away	-0.28	0.54	0.66	0.40	-0.04	0.16	0.04	0.02
Understand	0.79	0.06	-0.14	0.43	0.21	-0.08	-0.34	0.06
Speak	0.81	0.33	-0.09	0.18	0.02	-0.34	0.27	-0.10
Overall Freq	0.78	-0.03	0.31	-0.23	-0.39	-0.11	-0.05	0.28
Family Freq	0.54	0.50	0.08	-0.56	0.36	0.10	-0.04	0.01
Friend Freq	0.77	-0.28	0.41	-0.10	-0.14	0.06	-0.09	-0.35
ID	0.65	0.27	-0.54	0.10	-0.28	0.35	0.05	-0.03

PCA results on social variables

Figure 4.10 shows the results for the PCA on the sociolinguistic variables. As in the production experiment, Dimension 1 accounts for a large amount of the variance (46.7%). The contributions of the different factors to Dimension 1 are presented in Figure 4.11. Once again, Dimension 1 may be interpreted as *Tonal Language Experience* (TLE), as the highest contributing factors involve the relative usage of Thai/Lao as opposed to Kuy/Khmer. The remaining dimensions are less interpretable and so they are left alone—the correlation of each factor to each of the dimensions may be seen in Table 4.4. Because the effect of Time Away was difficult to interpret in the production results, it was left out of the perception analysis.

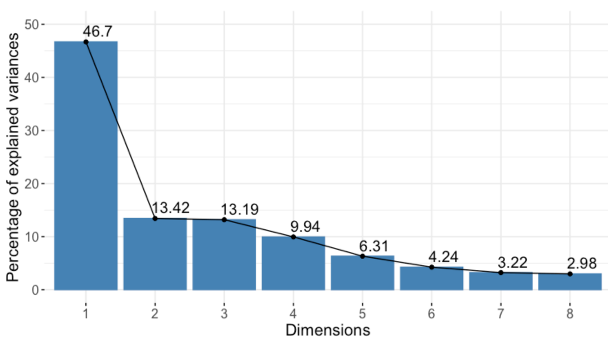


Figure 4.10: Scree plot for PCA on sociolinguistic variables in perception experiment

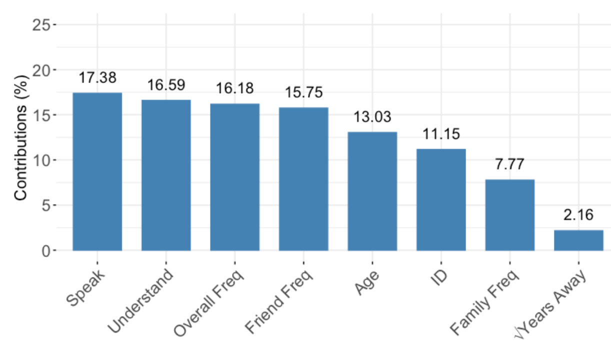


Figure 4.11: Contributions of each sociolinguistic variable to Dimensions 1

Table 4.5: Logistic regression summary table (* $p < .05$, ** $p < .01$, *** $p < .001$)

	Estimate	Standard Error	z	p	Significance
(Intercept)	.271	.234	1.16	.247	
OQ	3.253	.060	54.13	< .001	***
f0	-1.906	.053	-35.91	< .001	***
Gender (M)	-.072	.145	-.50	.618	
TLE	.173	.202	.86	.392	
OQ:f0	.512	.114	4.51	< .001	***
OQ:Gender (M)	.762	.091	8.33	< .001	***
f0:Gender (M)	-.314	.079	-3.99	< .001	***
OQ:TLE	.400	.117	3.42	< .001	***
f0:TLE	-.431	.103	-4.17	< .001	***
Gender (M):TLE	-.090	.291	-.31	.758	
OQ:f0:Gender (M)	.193	.171	1.13	.260	
OQ:f0:TLE	.151	.221	.68	.494	
OQ:Gender (M):TLE	-.491	.183	-2.68	.007	**
f0:Gender (M):TLE	-.047	.158	-.30	.767	
OQ:f0:Gender (M):TLE	.332	.343	.97	.332	

Logistic regression results

Table 4.5 provides the regression table from the logistic regression analysis. Of the notable higher level interactions, the three-way interaction between OQ, Gender, and TLE is significant, as is the interaction between f0 and TLE. Figure 4.12 shows the predicted results of the logistic regression analysis in a facet grid. Genders are represented by the columns, while TLE is represented by the rows. The "greater TLE" row shows the probability of a breathy response predicted for listeners with a TLE score 1.5 standard deviations above the mean, while the "lower TLE" row shows predictions for speakers with a TLE score 1.5 standard deviations below the mean. Values are visualized for 100 equally spaced OQ values between 30% and 70% OQ and at 3 f0 values (110 Hz, 125 Hz, and 140 Hz), represented by color. Ribbons around the lines represent 95% confidence intervals for the predictions.

Unsurprisingly, greater OQ and lower f0 values lead to more breathy responses. The interaction between f0 and TLE on the probability of a breathy response is noticeable when comparing the bottom graphs to the top ones: the response curves differ less from each other in listeners with lower TLE than in listeners with higher TLE, as can be seen by the larger space between the curves in listeners with higher TLE. Of particular note is the greater difference in responses to stimuli at the modal end of the spectrum as compared to the breathy end. At 30% OQ, a low f0 of 110 Hz leads to a mean estimated probability of $\sim$.35 and $\sim$.22 for breathy responses for lower TLE female and male listeners, respectively; however, it increases to $\sim$.44 and .46 for higher TLE listeners. The three-way interaction between OQ, TLE, and Gender can be seen in particular by

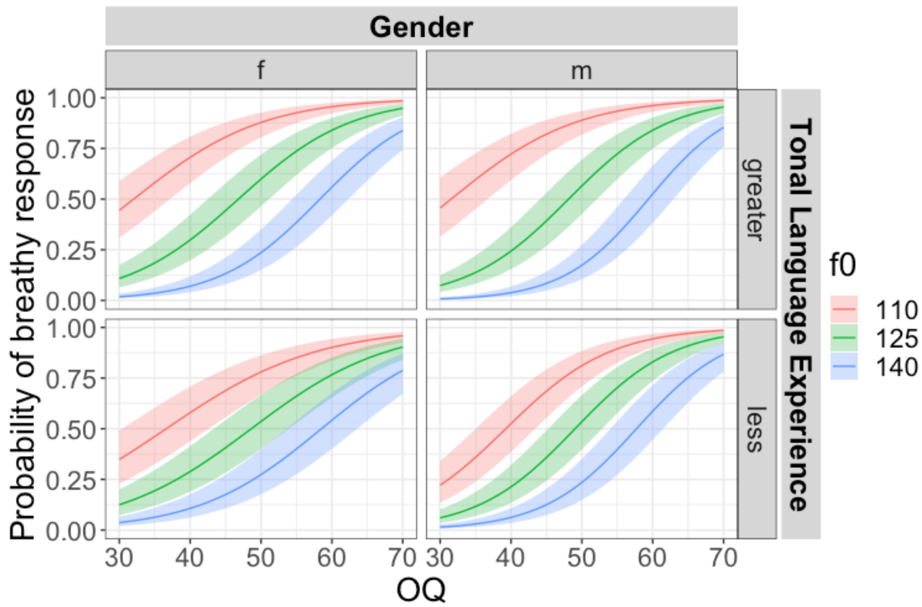


Figure 4.12: Results of logistic regression

comparing the curves between female and male listeners with lower TLE. The curve is more sigmoidal for male listeners, suggesting that OQ is a more distinctive cue for the register contrast for male listeners than for female listeners, as the responses at either end are more extreme.

Linear discriminant analysis results

The mean accuracy scores for each listener across the 10 test sets from the LDA analyses were used as proxies for the weight of the OQ cue and the weight of the f0 cue in distinguishing the modal and breathy registers. A weight of 1 would suggest that the listener is able to distinguish the two registers purely on that cue, while a weight of 0.5 would suggest that the listener is guessing at chance and that that cue offers no information. Table 4.6 shows the mean and standard deviations of the accuracy scores, subgrouped by gender, for each cue. For both genders, OQ is a much stronger cue for register than f0 is, on average. Thus, the overall listener population does *not* primarily rely on f0 to perceive register.

Figure 4.13 plots f0 weights against OQ weights on a scatterplot to visualize the relative importance of each cue to the register contrast. An identity line is included to indicate the set of points for which OQ and f0 weights are equal.

A notable pattern is that for all speakers except 2 female speakers and 1 male one, OQ is a stronger cue for the register contrast than f0 is, as can be seen by all the points above the identity line. This suggests that voice quality is still the primary cue in perception for the register distinction in this Kuy community. There is no tradeoff between the two cues, as the Pearson R correlations for both female ($r = .07, p = .69$) and male ($-.06, .73$) are insignificant. Another

Table 4.6: Mean and standard deviations of accuracy scores in perception, subgrouped by gender

	F		M	
	Mean	SD	Mean	SD
f0	.64	.05	.63	.05
OQ	.75	.06	.78	.06

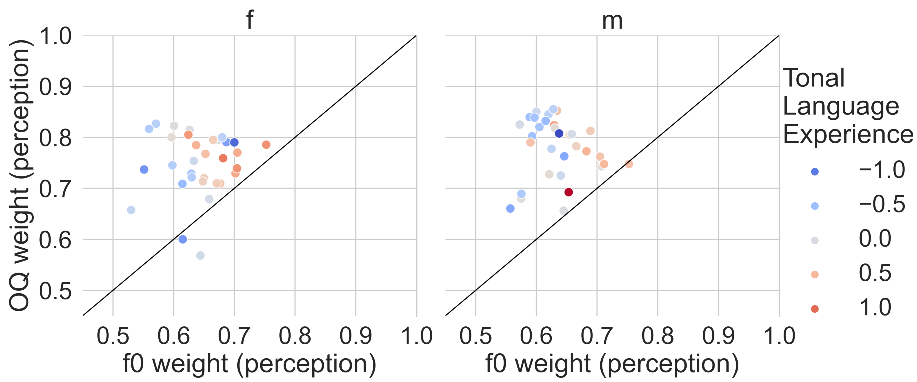


Figure 4.13: Correlations of OQ weights to f0 weights

clear pattern emerges in the clustering of red points to the right of the blue points for both genders. This clustering to the right suggests that speakers with greater TLE weigh f0 more heavily than their counterparts with lower TLE.

The Pearson correlation between f0 and TLE is positive and significant for both female ($r = .44, p < .05$) and male ($r = .46, p < .01$) participants, demonstrating that the aforementioned clustering of red points to the right is significant. These correlations are visualized in the top image in Figure 4.14. The correlation between OQ and TLE was also calculated, but did not yield significance for either female ($r = .15, p = .4$) or male ($r = -.18, p = .33$) participants. The relationship between OQ and TLE is visualized in the bottom image in Figure 4.14.

4.3 Discussion

The results support the hypothesis that greater usage of Thai/Lao is correlated with heavier weighting of f0 in perception for both female and male speakers at both the group and the individual levels. This is evidenced at the group level by the greater separation between the response curves when split by f0 for speakers with greater TLE and at the individual level by the significant positive correlation between accuracy of the LDA using only f0 information and TLE. The hypothesis that greater usage of Thai/Lao is correlated with lower weighting of voice quality in perception (using OQ as a proxy), however, is not fully supported by the results. At the group

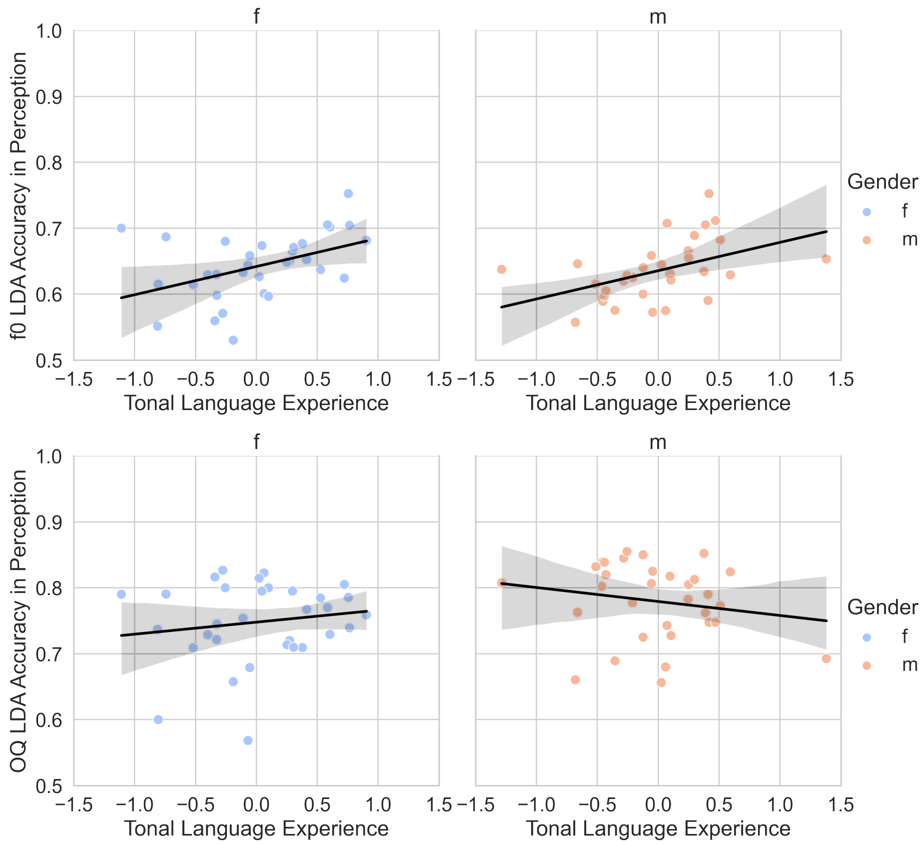


Figure 4.14: Correlations of f0 weights (top) and OQ weights (bottom) to TLE

level, female speakers with greater TLE show a steeper response curve than those with lower TLE, providing potential support for the effect of TLE on the weighting of voice quality in perception for female speakers. However, the individual level analysis provides no evidence for this hypothesis, as there is no significantly positive relationship between the LDA accuracy using OQ information and TLE for either female or male speakers.

It was also noted that the difference in responses to stimuli depending on f0 between those with lower TLE and those with greater TLE was greater for modal stimuli than for breathy stimuli. One possible reason for this asymmetry could be due to the fact that breathy voice does not feature in Thai nor Lao phonology. Listeners who have greater experience with Thai/Lao may perceive more f0 variation in their listening experience, but this variation would be associated with modal voice because of the lack of breathy voice in Thai and Lao. Since the variation would not be associated with breathy voice, it is possible that breathy stimuli are less susceptible to a changed percept from f0.

The differing patterns of response times by generation are also suggestive of the shift in the cue complex for the register contrast. Although no hypotheses were overtly tested with regards to response time, it could be seen that less extreme f0 values increased response times more for the younger generation than for the older one. This effect is reminiscent of findings by Whalen et al. (1992), who find slower response times for perceptual stimuli for the voicing contrast in English when f0 values are conflicting, even when VOT values are unambiguous. It appears that f0 provides more information for the register contrast for the younger generation, since their response times are more affected by f0 than for the older generation.

While the pattern for heavier weighting of f0 in perception by speakers with greater TLE is clear, I make no claim that f0 is overtaking voice quality in cuing the register contrast, particularly as the LDA analysis only shows greater accuracy using f0 information than using OQ information for 3 speakers.

4.4 Summary

The key findings of the perception experiment are the increased usage of the f0 cue in identifying register in Kuy for both female and male speakers who have more experience in Thai and Lao. There is no evidence of a decreased usage of voice quality with increasing tonal language experience, however, nor is there a tradeoff in usage of f0 and voice quality in identifying register. The results of the perception experiment with respect to the hypotheses may be summarized as follows:

1. Greater usage of the tonal languages Thai and Lao, relative to the non-tonal languages, Kuy and Khmer, will lead to increased reliance on pitch cues in the Kuy register contrast

   ⋆ Hypothesis is supported for both female and male speakers

2. Greater usage of the tonal languages Thai and Lao, relative to the non-tonal languages Kuy and Khmer, will lead to decreased reliance on voice quality cues in the Kuy register contrast

   ⋆ Hypothesis is unsupported

3. There is a tradeoff between f0 and other register cues

   ⋆ Hypothesis is unsupported

Chapter 5

The perception-production link for Kuy register

While the previous chapters demonstrated different effects of Tonal Language Experience on the production and perception of the register contrast in Kuy, we have yet to explore the effects on production and perception in tandem. As 37 participants overlapped between the two experiments, within-speaker differences can be analyzed to understand the relationship between production and perception of the Kuy register contrast. This chapter delves into the well-studied topic of the alignment of production and perception and whether there are any discernible group-level patterns. As this question is set against the background of multilingualism and language contact, this alignment will be examined in relationship with language experience, as in the individual experiments. §5.1 summarizes information about the participants who overlapped in both studies and explains how methods were applied in this analysis, §5.2 presents the results of the analysis, and §5.3 discusses the implications of the results and future directions for research.

5.1 Methodology

Summary of participant data

The age and gender of the 37 participants overlapping between the two experiments is presented in Table 5.1. While there is, coincidentally, some balance in the dataset, there is an underrepresentation of female participants in their twenties and male participants in their fifties. Of these participants, 27 are from Ban Khi Nak, 5 from Ban Rong Ra, and 5 from Ban Khi Nak Noi.

Application of methods to perception-production link

The first method to be applied in this chapter is PCA. PCA is carried out on the 37 participants who overlapped between the two experiments, using the same sociolinguistic variables from those experiments to yield a dimension that encapsulates much of the sociolinguistic variance. A new PCA is run rather than using the PCA values from either the production or perception experiment,

Table 5.1: Ages and genders for participants overlapping between production and perception experiments

	20s	30s	50s	60s
F	2	6	6	6
M	4	5	2	6

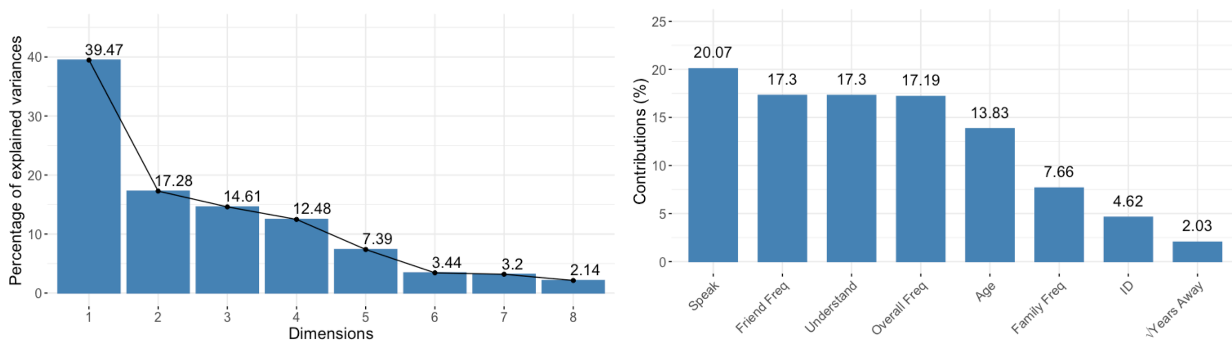


Figure 5.1: Results of PCA on participants overlapping in both experiments (left: scree plot; right: contributions to Dimension 1)

as the PCA values for a given participant will inherently depend on the other participants in the pool. Thus, as a caveat given the smaller sample size, it should be noted that the PCA values may not be as representative as if the population were larger.

The results of the LDA from the production and perception experiments are compared to one another, while taking into account language experience. Comparisons are analyzed using Pearson R correlation to determine the strength of the relationship between production and perception cue weights, as well as the relationship between these weights and language experience. The calculation of a combined production-perception cue weight is described in §5.2 for ease of comprehension.

5.2 Results

PCA results on social variables

The left scree plot in Figure 5.1 shows results for the PCA on the sociolinguistic variables. Again, Dimension 1, which accounts for 39.47% of the variance, may be interpreted as *Tonal Language Experience* (TLE), as the highest contributing factors relate to the relative usage of Thai/Lao as opposed to Kuy/Khmer. The correlation of each factor to each of the dimensions may be seen in Table 5.2.

Table 5.2: Correlation of social factors to each dimension in production-perception PCA

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Age	0.66	0.03	-0.60	0.11	0.29	0.29	0.11	0.09
√Years Away	-0.25	0.58	0.42	0.61	-0.06	0.09	0.20	0.07
Understand	0.74	-0.17	-0.16	0.52	0.13	-0.26	0.05	-0.20
Speak	0.80	-0.15	0.24	0.33	-0.21	0.10	-0.33	0.12
Overall Freq	0.74	0.43	0.18	-0.31	-0.23	0.19	0.03	-0.25
Family Freq	0.49	0.07	0.62	-0.25	0.55	-0.04	-0.01	0.05
Friend Freq	0.74	0.44	-0.17	-0.26	-0.21	-0.26	0.11	0.19
ID	0.38	-0.79	0.32	-0.06	-0.21	0.06	0.28	0.05

Table 5.3: Relative reliance on different register cues in perception as compared to production

	f0		Voice quality	
	F	M	F	M
Perception > Production	11	7	15	10
Production > Perception	9	10	5	7

Comparing LDA results of perception to production

Figure 5.2 shows the correlation of the LDA accuracy utilizing only f0 (top image) and voice quality (bottom image) information in perception as compared to production. The LDA accuracy for OQ in perception is compared to the LDA accuracy for the combined VQ measure in production. Here, the identity line in black represents the point at which perception and production are perfectly aligned. Speakers underneath the identity line rely on the given cue more in perception than in production, while those above the identity line rely on that cue more in production than in perception.

The f0 graphs show that speakers are relatively evenly distributed around the identity line, suggesting that there is a relatively diverse mix of Kuy speakers who reliably use f0 in perceiving the register contrast but who may not use f0 differences as reliably in producing the contrast, speakers who reliably use f0 differences in producing the contrast but who may not use f0 as reliably in perceiving the contrast, and speakers who use f0 relatively equally reliably in both producing and perceiving the contrast. Meanwhile, the voice quality graphs show that there are more speakers who use voice quality reliably in perceiving the register contrast but less so in producing it than there are speakers who use voice quality reliably in producing the contrast in comparison to perceiving it. Table 5.3 summarizes the counts for the comparison of perception to production weights for each cue.

Another dimension of interest is the cue weight taking *both* perception and production into account. In looking at the f0 graphs in Figure 5.2, we can see a pattern of red points (those

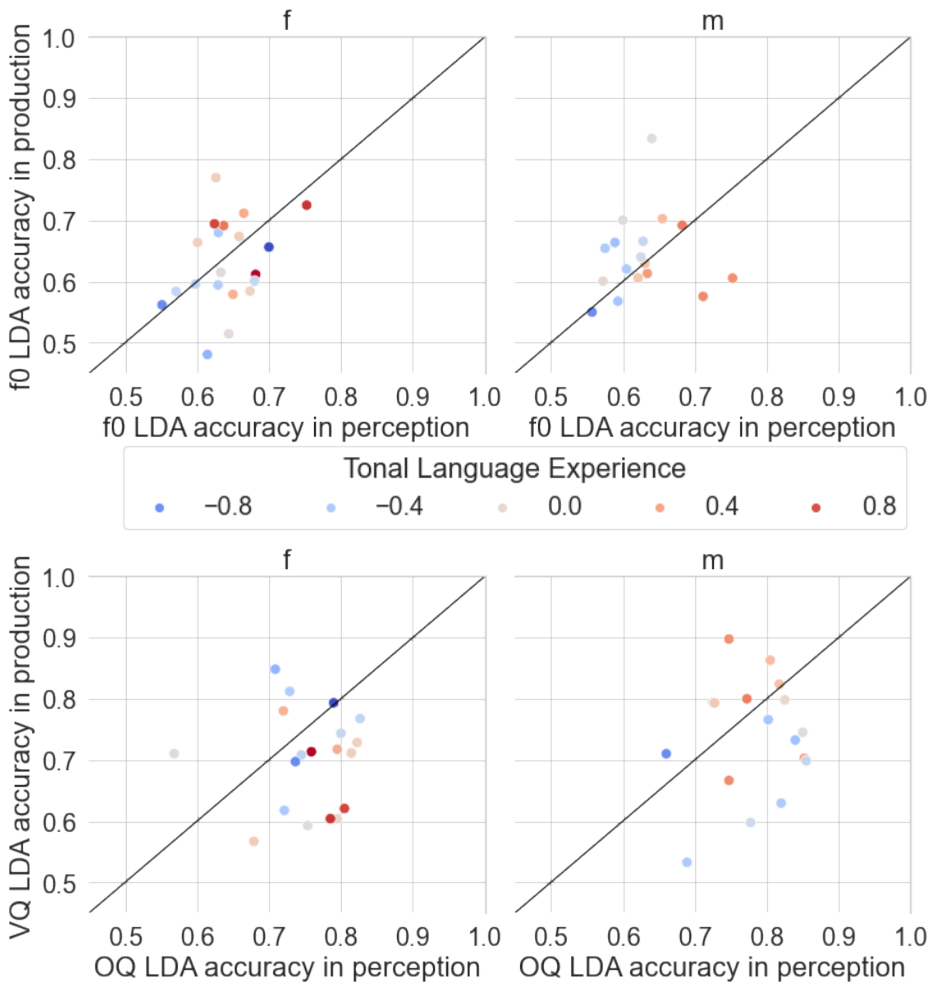


Figure 5.2: Comparison of LDA performance using f0 (top) and voice quality (bottom) in perception vs. production

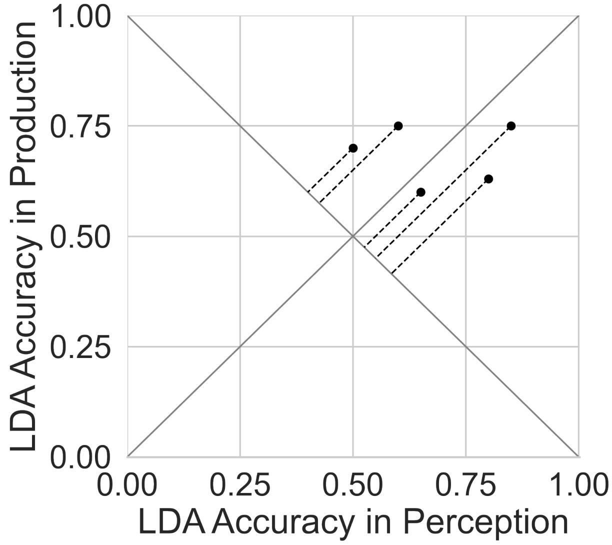


Figure 5.3: Explanation of calculating combined perception and production cue weight

with relatively higher TLE) clustered to the "northeast" of blue points, suggesting that those with greater TLE show heavier weighting of f0 in both perception and production. In order to quantify this "northeastness", we can calculate the distance of each point from the line defined by $y = -x + 1$, which cuts through (0.5, 0.5), the point at which the cue provides no meaningful information for either perception or production. This calculation is essentially the same as getting the x-coordinate of the point if the axes were rotated 45 degrees counterclockwise. This idea is schematized in Figure 5.3, with the solid lines representing the rotated axes and the dotted lines representing the "new x-coordinate" or distance from the line $y = -x + 1$.

The Pearson R correlation of this distance with TLE was calculated and found to be significant for both female ($r = .5, p < .05$) and male ($r = .55, p < .05$) participants for f0, demonstrating that higher TLE speakers show heavier f0 weighting when taking into account both perception and production than their lower TLE counterparts do. For male speakers, however, this seems to be largely driven by the increased f0 accuracy in perception, as can be seen by the fact that the red points cluster mostly to the *right* of the blue points in the graph of male speakers. For voice quality, however, there is no significant relationship for either female ($r = -.28, p = .22$) or male ($r = .45, p = .07$) participants, although the medium effect size and p value of .07 for male participants is of note. These relationships are presented in Figure 5.4

Comparing LDA results for individual voice quality cues in production to perception

The graphs in Figure 5.5 compares the OQ accuracy from perception to the three measures (H_1*-H_2*, H_1*(-A_n*), and CPP) that make up the VQ measure in the LDA analysis for production. Except

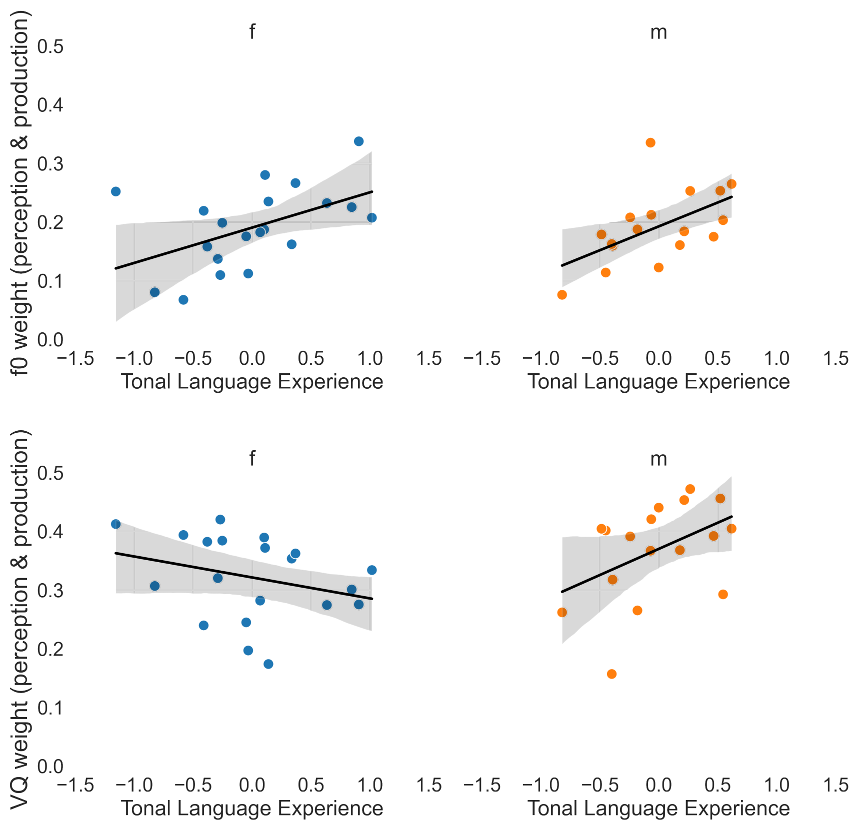


Figure 5.4: Combined perception and production weight compared to TLE for f0 (top) and VQ (bottom)

for 3 male speakers who weigh H_1*-H_2* in production more heavily and 1 female speaker who weighs H_1*(-A_n*) in production more heavily than OQ in perception, the overwhelming majority of speakers weigh OQ more heavily in perception than they do these cues in production. There are a number of possibilities for this large imbalance: (1) Although OQ is considered an articulatory correlate of the acoustic H_1*-H_2* cue, it may be the case OQ is better approximated by a combination of H_1*-H_2*, H_1*(-A_n*), and CPP, as the combined VQ cue is more balanced with OQ. (2) OQ is mostly approximated by H_1*-H_2* and it is the case that speakers overall rely on this cue more in perception than in production. (3) The synthetic Klatt parameter OQ does not correspond well to articulatory OQ, but does correspond well to a combination of H_1*-H_2*, H_1*(-A_n*), and CPP.

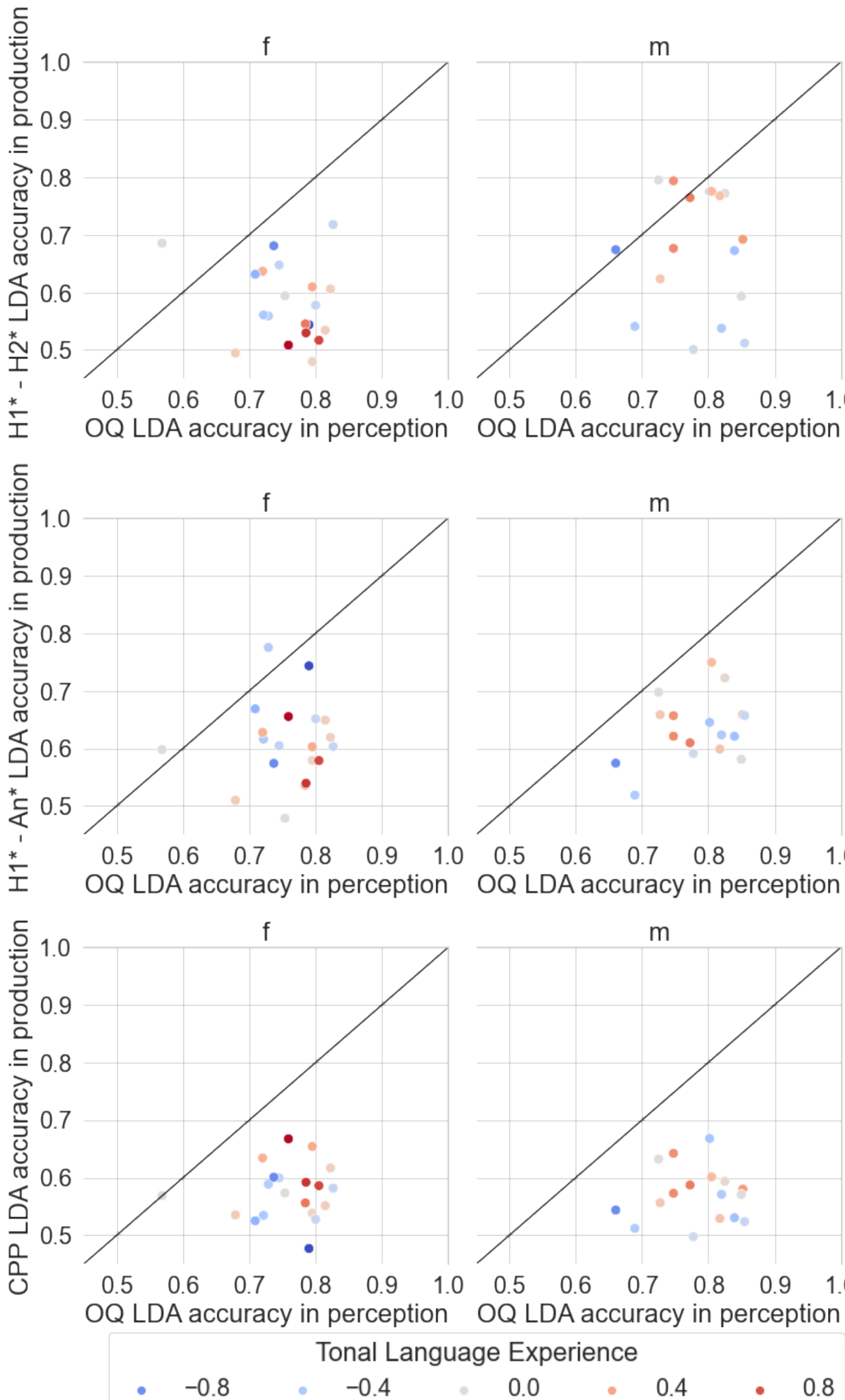


Figure 5.5: Comparison of LDA performance for different voice quality cues in production vs. perception

5.3 Discussion

The small sample size for participants who took part in both the production and perception experiments prevents us from drawing any strong conclusions. However, the pattern of speakers with more TLE weighing f0 more heavily overall in production and perception appears to be a promising pattern. Meanwhile, there is no clear relationship between the weighing of voice quality and TLE. Also notably, the number of female speakers who rely on voice quality in perception is much greater than the number of female speakers who rely on it in production. The pattern here suggests that female speakers may potentially be shifting towards losing the voice quality contrast in favor of a pitch contrast in production of the register contrast, but overall, the community still relies on voice quality as a cue for the register contrast in perception. Thus, perception appears to be more conservative than production in relying on voice quality more for the register contrast. The lagging of perception in cue shifts has also been shown for Afrikaans (Coetzee et al., 2018) and Dutch (Pinget et al., 2020). Such a pattern may not be surprising, given that a conservative cue for a contrast is expected to still be informative even for innovative speakers in order to accommodate listening to conservative speakers.

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 specifically tied to language usage itself. Unfortunately, because age is strongly tied to language usage, with the younger generation showing more frequency and proficiency in Thai than the older generation, these factors are difficult to tease apart. However, we can attempt to observe variation within age groups. In both graphs in Figure 5.6, Age is plotted against f0 accuracy, with points shaded for TLE. The left graph shows results from the production experiment, but only with female speakers as male speakers did not show a significant relationship between f0 and TLE. The right graph shows results from the perception experiment for both women and men; gender is indicated by the shape of the point. There is a strong significant negative correlation between Age and TLE for both production ($r = -.59, p < .001$) and perception ($r = -.7, p < .001$), unsurprisingly. However, what is noticeable are the points that are shaded blue lying generally below the regression line in the 20–39 age range and the points that are shaded red lying generally above the regression line in the 50–69 age range. The sample sizes are too small to claim that these patterns are necessarily meaningful, but the trend suggests the possibility of TLE being responsible for heavier f0 cue weights *separately* from age. In order to tease these factors apart more, we would need to observe cue weighting in more younger speakers with low TLE and more older speakers with high TLE.

Asymmetries in the findings

As seen in the results of both experiments, women and men show different patterns of register cue usage. Women show increased usage of f0 alongside greater TLE in both production and

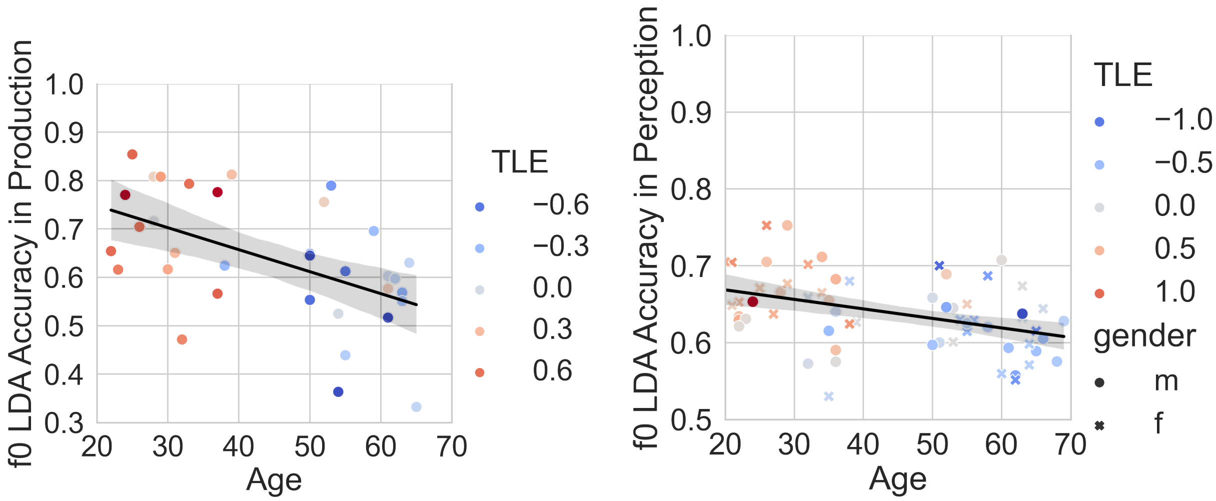


Figure 5.6: Correlation of age to f0 cue weights (left: women in production; right: both women and men in perception)

Table 5.4: Production and perception patterns with increased TLE (green arrows indicate a match with the hypotheses and red arrows indicate the opposite result expected from the hypothesis)

	f0		VQ	
	F	M	F	M
Production	↑	-	-	↑
Perception	↑	↑	-	-

perception, while men show increased usage of f0 alongside greater TLE only in perception. Men also unexpectedly show *increased* usage of voice quality cues (especially H_1*-H_2*) in production, alongside a reduced usage of F1 cues. Neither show any effect of greater TLE on the usage of voice quality cues in perception. While women with greater TLE appear to weigh voice quality relatively less in comparison to their lower TLE counterparts in perception, as can be seen in the logistic regression analysis, this tendency does not appear to reach significance. These patterns are summarized in Table 5.4.

A question that follows is why women would match the hypothesis in relation to f0 cues for both production and perception, but men only match the hypothesis for perception. In §3.3, differences in the life trajectories and social circles of members of the Kuy community, depending on their gender, were highlighted to attempt to explain the asymmetry between men and women in production. Here, I look at potential reasons for a gender asymmetry in production, but not in perception.

If Kuy speakers use Thai/Lao regularly, the articulatory settings that they use while speaking these tonal languages may permeate into their usage of Kuy. Research has shown that code-switched utterances differ phonetically from unilingual utterances (Piccinini and Garellek, 2014; Fricke et al., 2016; Shen, 2020). Code-switching in the Kuy community I stayed with was commonplace, and it was not uncommon to hear any mix of the four languages in a given dialogue. Code-switching between Kuy and Thai or Lao may bias articulatory settings towards those that are conducive to greater differences in f0. Support for this idea comes from the mirrored findings from Pratankiet (2001) and Sipipattanakun (2014) that Kuy (and Khmer) speakers have narrower f0 ranges when speaking Lao and Thai. The mechanisms used in *perception* of Thai/Lao are not necessarily expected to bleed over into perception of Kuy: in hearing larger f0 differences for tonal contrasts in Thai/Lao, listeners should be expected to learn that these are important for contrast *in Thai/Lao*.

A key piece of the puzzle may come from looking at the comparison between the LDA accuracy scores for f0 and VQ in production (final graph of Figure 3.21) and between those for f0 and OQ in perception (Figure 4.13), which are reproduced in Figure 5.7. In comparing these two graphs, we can see that while a fair number of participants (15) weigh f0 more heavily than VQ in production, only 3 weigh f0 more heavily than OQ in perception. Thus, despite the fact that TLE is correlated with greater usage of f0 for *both genders* in perception, very few speakers use it more reliably than voice quality. On the other hand, a fair number of female speakers and a handful of male speakers *do* use f0 more reliably than voice quality in production, although the male speakers who do so actually have lower experience with tonal languages.

The pattern appears to suggest that in production, when there *is* an effect of TLE on the usage of f0, the effect is strong enough to the point of leading f0 to be a more reliable cue than voice quality, whereas in perception, the effect of TLE is present over the whole population, but rarely leads to f0 being a more reliable cue than voice quality. Research has shown the clear effect of even short-term experience in a second language on the production of a first language contrast (Sancier and Fowler, 1997; Chang, 2010). The effect of second language experience on perception of first language contrasts is also documented (Dmitrieva, 2019). However, the weaker effect from multilingualism on shifting cue usage in perception may be due to less integration of different languages in perception in comparison to production: while people must account for interspeaker differences and be able to handle a large amount of variation in perceiving language, their production is not as variable as their perception, although there can be accommodation effects. Thus, their perceptual repertoire should be more expansive than their articulatory one. Because of this, there may be more permeability of articulatory repertoires but less of perceptual repertoires between different languages.

How do we reconcile the finding that TLE has an effect on perception for *both* female and male speakers with the finding that the effect of TLE is *stronger* in production, but *only* for female speakers? One possible reason for the effect on perception across women and men is that, especially in the present day, hearing Thai is unavoidable—it is heard in schools and through media constantly, through both television and social media, which are facets of everyday life in the Kuy community. Thus, there is a baseline level of exposure to hearing Thai already that exists regardless of one's social circles. Those with more experience using tonal languages may therefore be primed to show some effects of cue shift, but the effects may be subtle because of the separation

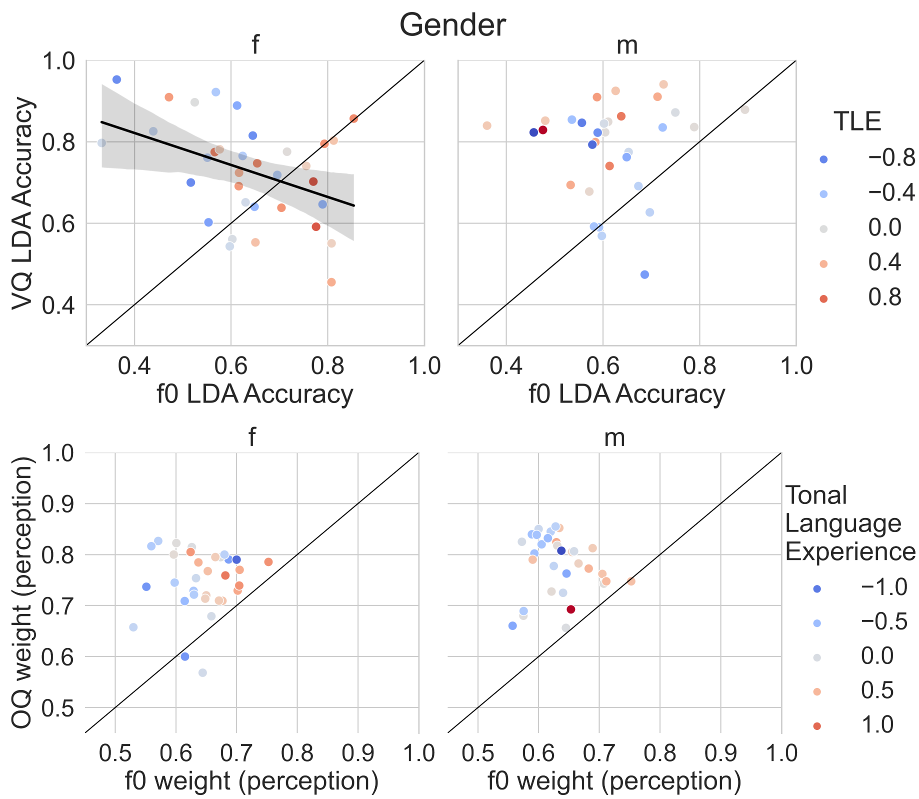


Figure 5.7: Correlations of f0 to VQ in production (top) and to OQ in perception (bottom)

of perceptual repertoires for different languages. On the other hand, even with the pervasiveness of *hearing* Thai, it is plausible that many speakers with less tonal language experience go about their lives using little to no Thai. There is likely more variability in how much Thai/Lao individual Kuy speakers speak than there is in how much they hear. This variability, combined with the permeability of articulatory repertoires across different languages, may be a source for the simultaneous findings of no effect for men and a greater effect on production than on perception for women.

The other pattern of note is the lack of weakening of voice quality cues from effects of bilingualism in a tonal language. While the weakening of a primary cue in a contrast due to bilingualism in another language is documented in the literature, many of these studies focus on contrasts that are *perceptually equivalent* in the two languages.[1] An important follow-up question is whether the Thai/Lao tonal contrast is perceptually equivalent to the Kuy register contrast. There does not seem to be evidence that they are, and perhaps it is this lack of equivalence that prevents the waning of voice quality in perception of the contrast. Other studies documenting

[1]For example, see Dmitrieva (2019) for evidence of lesser reliance on glottal pulsing in favor of vowel duration in the Russian voicing contrast by L1 Russian, L2 English bilinguals. The Russian and English voicing contrasts are assumed to be perceptually equivalent, following the Perceptual Assimilation Model (Best and Tyler, 2007).

loss of contrast due to bilingualism investigate endangered languages where language attrition is taking place (Aikhenvald, 2020). Although Kuy is certainly endangered, the participants in the current study may not be experiencing attrition to the point of losing voice quality as a relevant cue in the register contrast. Thus, the results do not support the strong hypothesis that usage of languages that do not employ voice quality in contrast affects one's existing usage of voice quality in a language that does employ it. This result is also congruent with the idea that perceptual repertoires need to be kept broader—because voice quality is still a "primary cue" used by the community, it is important to maintain in the perceptual repertoire.

These results suggest that *in cases of multilingualism*, it may be the case that production of contrasts may be inherently conducive to integration due to speakers handling one articulatory source, whereas perception of contrasts may be more resistant to it due to listeners recovering information from multiple sources. The integration in production may be what results in the greater potential for *tradeoffs* in a phonological contrast: here, there is evidence for a tradeoff between voice quality and f0 cues in production for women. On the other hand, in the perception results, we only see *additive effects*: there is evidence for enhancement of f0 cue usage in perception of the register contrast due to its usage in tone, but not for attenuation of voice quality cue usage, despite its lack of usage in tone. While literature has found tradeoffs in cue weighting in perception, those findings involved *perceptually equivalent contrasts*. Thus, it may be the case that perceptual assimilation leads to the integration of different linguistic repertoires at a level similar to that in production. In other words, cues may compete in production due to a unified articulatory source and in perception if contrasts are perceptually unified, but may not do so in perception if the contrasts are seen as separate.

Testing hypotheses

Without further evidence, the discussion above remains speculative. Thus, to test these hypotheses about additive effects vs. tradeoffs due to the difference between integrated and separated systems, future studies should explore cue usage in the tonal contrasts in Thai and Lao by these same speakers. The hypotheses for usage of f0 in Thai and Lao, with respect to the findings in Kuy, are as follows:

- ⋆ If production is integrated, f0 cue weights in the Kuy register contrast should be positively correlated with f0 cue weights in the Thai and Lao tonal contrasts
- ⋆ In perception
  - ○ If the Kuy register contrast is not perceptually equivalent to the Thai tonal contrast as we predict, f0 cue weights in the Kuy register contrast should not necessarily hold any correlation with f0 cue weights in the Thai and Lao tonal contrasts
  - ○ If the register contrast *is* perceptually equivalent to the Thai tonal contrast *or* perception across the two languages is integrated, then f0 cue weights should be positively correlated with f0 cue weights in the Thai and Lao tonal contrasts

As for voice quality, it is unclear that cue weights in the Kuy register contrast would be correlated with any use of voice quality in Thai or Lao—there is evidence of prosodic and sociolinguistic uses of voice quality (Abramson, 1962, 1979; Hudak, 1990; Potisuk et al., 1999; Hudak, 2008; Thepboriruk, 2009) and of creakiness in some contexts in phonemically voiced stops in Thai (Esling et al., 2005) and glottalization in Lao tone (Brown, 1965; Hoonchamlong, 1984, Sipipattanakun, 2014, 109), but the relationship between breathy voice and tone does not hold the same regular relationship as f0 does to register contrasts in Kuy.

Structural factors in change

Potentially relevant to these changes at the suprasegmental level in Kuy is the fact that the shifting of cue weights in the register contrast takes place not in a vacuum, but alongside other changes. As mentioned in §1.2, three other changes in this speaker population are the dropping of the syllabic nasal, the merger of /tr/ with /kr/, and the merger of coda /r/ with /l/. Sukkasem (2005) attributes the final change to contact with Thai and Lao as both languages do not allow coda /r/. The loss of syllabic nasals is not described by Sukkasem, but as Thai and Lao lack syllabic nasals, it is not improbable that this change could be related to contact as well.

Among the production experiment stimuli (including both targets and distractors), there were 19 with syllabic nasals, 5 with /tr/, and 4 with coda /r/. In order to explore whether these changes could be related to contact as well, the percentage of tokens preserving each feature is calculated for each participant in the production experiment and compared to TLE in Figure 5.8. As can be seen, the coda /r/ ∼ /l/ merger is quite advanced, with most speakers producing *no* coda /r/ and no speakers preserving coda /r/ fully. The loss of the syllabic nasal and the /tr/ ∼ /kr/ merger, on the other hand, appear to be progressing at a similar rate to each other. The patterns are similar regardless of gender. For both these changes, there is a clear pattern where loss of the conservative feature is more advanced in those with more experience in tonal languages, providing potential evidence for at least these two changes also being related to usage of Thai and Lao. Recall that TLE is meant to be a proxy for usage of Thai and Lao in comparison to Kuy and Khmer—in this context it is not the *tonality* of these languages that is relevant, but rather the Thai/Lao syllable structure.

The loss of the syllabic nasal has implications for the functional load of the register contrast as it reduces sesquisyllabic words to monosyllabic ones, creating new minimal pairs. For example, if the syllabic nasal is dropped in the word /ŋkɛːŋ/ 'waist', it becomes /kɛːŋ/, forming a minimal pair with /kɛ̤ːŋ/ 'side'. Sesquisyllabicity has been proposed to be an intermediary step on the way to monosyllabicization (Brunelle and Pittayaporn, 2012; Pittayaporn, 2015), a process that has been cited as a catalyst for tonogenesis due to the pressure on the suprasegment to maintain contrast to compensate for the loss of segments (Matisoff, 2001; Michaud, 2012; Kirby and Brunelle, 2017). While the mergers of coda /l/ and /r/ and of onset /tr/ and /kr/ do not affect syllable structure itself, they *do* simplify the onset and coda inventories, leading to fewer contrasts at the syllable level. With these changes promoting monosyllabicity and fewer segmental contrasts, what results is increased functional load on register and a greater pressure to prevent merger by preserving the register contrast in some form.

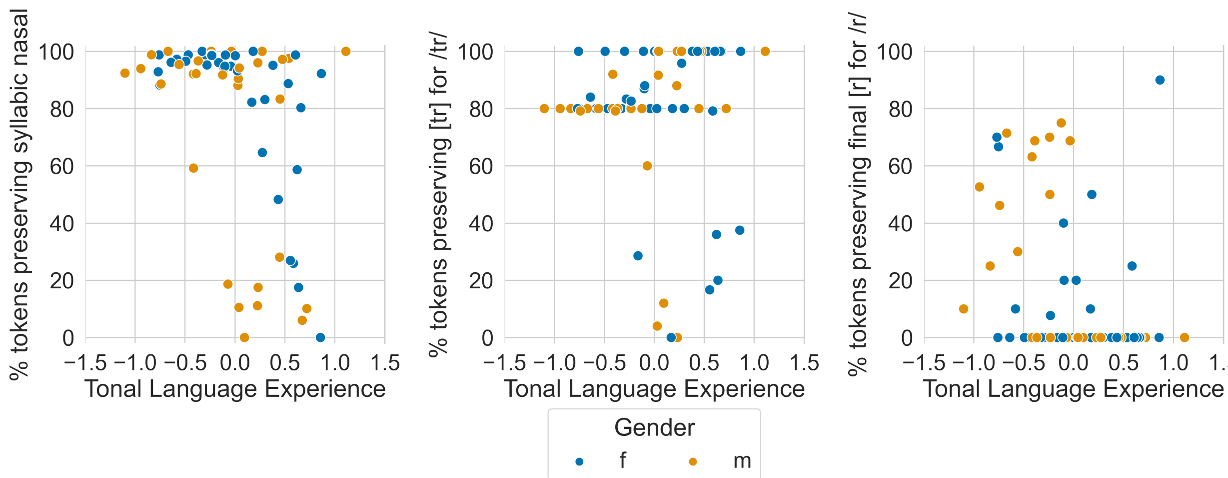


Figure 5.8: Preservation of conservative features by Tonal Language Experience

Kirby (2013) argues that the probability of a cue being selected for enhancement is a function of its *informativity*, the reliability with which a cue contributes to accurate identification of a speech sound. There are a host of cues that reliably cue register that could be selected for. If bilingualism in a tonal language increases the informativity of f0 because of greater sensitivity to it, then there could be a bias for f0 to be selected for, as what appears to be happening with women in production. However, other cues such as voice quality or F1 could also be selected for. In the case of men with more experience in Thai/Lao, cue weights are not transferred to f0 for male speakers, as hypothesized, but instead, voice quality appears to be the cue that is enhanced.

The aforementioned three changes reduce syllabic complexity and the inventory of onset and coda possibilities, leading to greater functional load on the suprasegment. As such, enhancement of cues in the register distinction would play an important role in preserving contrast. It may be the case that for female speakers, the confluence of pressure on the suprasegmental feature, combined with ability in tonal Thai and/or Lao, primes stronger f0 cue weighting, but for male speakers, usage of Thai and/or Lao is not enough to push changes in the direction of f0, but rather the pressure simply enhances the primary cue of voice quality. If greater functional load is indeed related to cue enhancement, we might expect the realization of these changes to be correlated with informativity of f0 for women and voice quality for men. Figures 5.9 through 5.11 explore this idea through visualizing the rate of preservation of the three aforementioned features as compared to the LDA accuracy, a proxy for informativity, of f0 (left graphs) and voice quality (right graphs), split by gender and with TLE colored for reference. It can be seen in 5.9 that female speakers who drop the syllabic nasal more have a slight tendency to show higher f0 cue weights. Male speakers who drop the syllabic nasal more may also show the same slight tendency, but for VQ weights; however, this pattern seems less convincing. For the /tr/ ∼ /kr/ (Figure 5.10) and coda /r/ ∼ /l/ (Figure 5.11) mergers, however, there is no discernible pattern.

While the syllabic nasal graphs show some *potential* evidence for the idea that monosyllabiza-

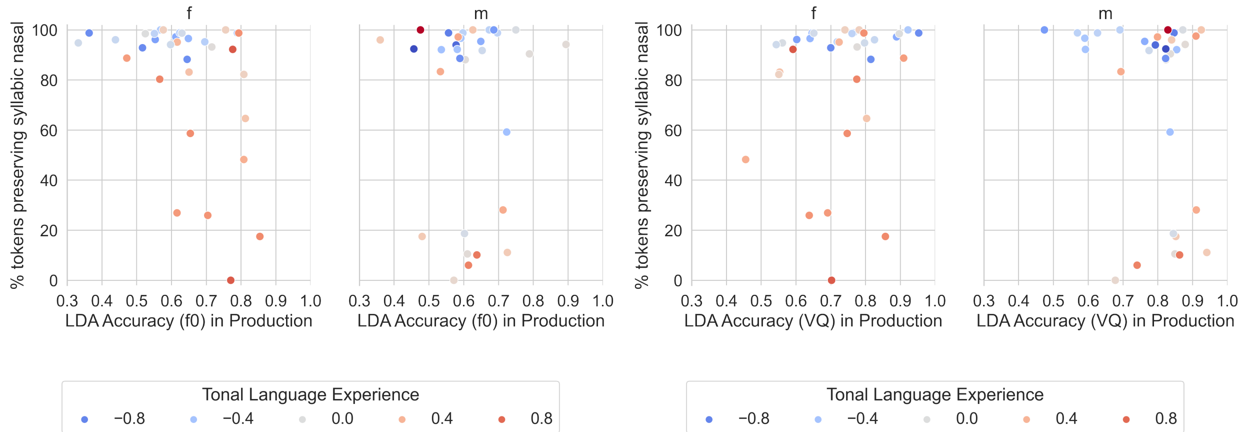


Figure 5.9: Preservation of syllabic nasal by informativity of f0 (left) and OQ (right)

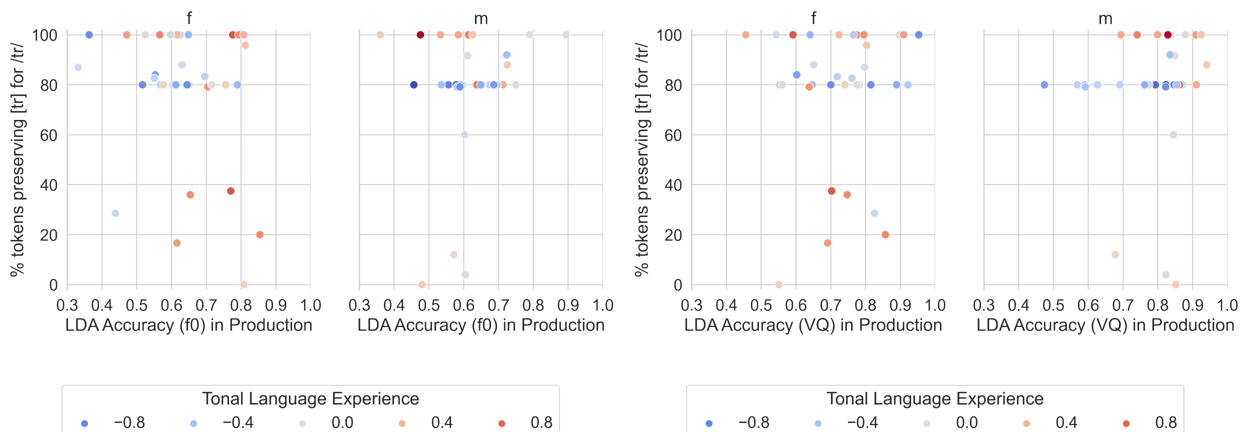


Figure 5.10: Preservation of [tr] by informativity of f0 and OQ

tion may play a role in cue enhancement for women, the relationship between functional load and cue enhancement appears to be tenuous in this case. Of course, as this data was not controlled for and the number of words represented is very small it is also difficult to draw any conclusions, and so a detailed investigation of these changes should be left to further study.

5.4 Summary

In comparing production to perception, there are mixed results, although the clear patterns appear to be the effect of TLE on f0 cue usage for women across the board and for perception across both genders. This finding follows a trend that has been shown across various different societies throughout the world—that of women being leaders of sociolinguistic change (Eckert, 1989;

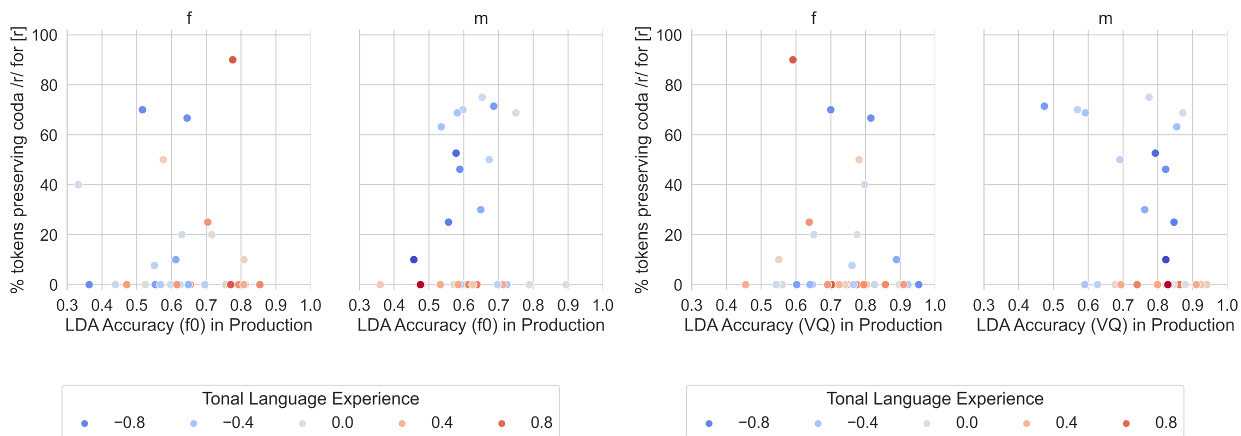


Figure 5.11: Preservation of coda [r] by informativity of f0 and OQ

Labov, 2001; Eckert and McConnell-Ginet, 2003; Alfaraz, 2010; Otheguy and Zentella, 2011).[2]. Of course, the reason for this asymmetry is not rooted in any intrinsic factor related to gender, but rather the differing experiences between women and men due to their roles in society. In Kuy, this difference is reflected in the different occupations taken up by women and men, particularly when living in other parts of Thailand. The nature of women's occupations as ones that lead to the creation of looser social networks leaves greater room for change to occur.

Because perceptual and articulatory spaces are inherently different, there are issues with comparing them directly (Schertz and Clare, 2020) and so it must be kept in mind that the findings must be qualified by this fact. While I speculated on a number of reasons that could explain the results, what is vital is both a deeper investigation of cue usage in all four languages used by this Kuy community, in other multilingual minorities of Thailand that speak a tonal language, and of multilingualism and cue usage in general. These studies provide only a first step into this complicated question.

[2]Of course, this pattern is not completely universal: see Bakir (1986) for a case study from Classical and Iraqi Arabic, for example.

Chapter 6

Conclusion

6.1 Summary of analyses and findings

My goal in carrying out these studies was to understand the ways in which multilingualism can contribute to the reorganization of phonological categories. While a language's phonological systems and structural biases play an important role in change, another important part is how language usage patterns can interact with these existing systems to precipitate change. The larger question I wanted to explore was how areal features come about and how we might be able to understand large-scale language convergence as a combination of language-internal and language-external factors. To this end, I investigated the register contrast in Kuy and the influence of multilingualism in tonal languages such as Thai and Lao on its change.

The findings paint a complex picture of the interaction of language usage and the multidimensionality of a phonological contrast. While there is promising evidence for the effect of experience in a tonal language on the enhancement of the usage of pitch cues, the effect is not uniform: in Chapters 3 and 4, I demonstrated that while women with more tonal language experience weigh f0 more heavily in the Kuy register contrast in both production and perception, men appear to do so only in perception. Furthermore, the effect of language experience on production was absent for men, but for women, the effect was stronger in production than in perception. I did not find evidence, however, for the attrition of voice quality cues as also hypothesized—in fact, men actually *increase* their usage of voice quality with tonal language experience. In production, however, women did show a tradeoff between the usage of f0 cues and voice quality cues, regardless of tonal language experience. The findings also revealed that tonal language experience can lead f0 cues to be a better cue than voice quality in the register contrast for many women in production; however, in perception, despite the effect of tonal language experience on f0 cue usage, voice quality still prevails over f0 as the primary cue for register.

Chapter 5 showed some evidence for a relationship between language usage and f0 cue usage overall in perception and production for women and also demonstrated the robustness of the voice quality cue in perception when compared to production, suggesting that even if there is some shift towards the usage of f0 cues in production for female speakers and in perception for both female and male speakers, voice quality does not appear to be losing ground as an informative cue in perception.

In the discussion that ensued in Chapter 5, I then suggested that the gender differences may be due to the differing social networks of women and men in Kuy society, particularly in the jobs they take when living in non-Kuy-speaking areas. Because Kuy women tend to take up occupations involving more social interaction when living in non-Kuy speaking areas, they may have larger and less dense social circles than men do. Weak ties, which have been shown to be conducive to language change, may be a key component in why women robustly show a relationship between f0 and tonal language experience across the board.

Structural factors were also discussed—as both men and women with more tonal language experience, and therefore more experience in Thai and Lao, show syllable structures that appear to conform more closely to Thai and Lao monosyllables, there may be an increasing pressure on the suprasegment to maintain contrast. While I suggested that this might be a factor effecting greater f0 cue usage in women but greater voice quality cue usage in men, the data was too limited to make any conclusions, and so the exact interactions between phonological structure and change that may be catalyzed by social factors merit more detailed study.

6.2 Zooming out to the broader perspective

The interactions that were explored in this dissertation may be schematized in Figure 6.1. Here the green circles—the phonological contrast in a given language (L_x) and variation in the phonetics with which that contrast is realized—sow the seeds from which sound change may spring. The blue circles on the left represent factors that may mediate the relationship between the phonological contrast and its phonetics. Naturally, the phonological system of the language plays a role: gaps and asymmetries may push phonetics in a certain direction. If the speaker is bilingual in another language (L_y), that phonological system will mediate the relationship between the contrast and its phonetics. One way in which the phonological system of the other language could influence the phonology-phonetics relationship is by increasing the informativity of cues that are highly informative in that language, thereby catalyzing the redistribution of cue weights, as suggested by the results of these studies.

At a higher level, social factors constrain and shape the linguistic landscape, altering usage patterns, which can in turn lead to shifts in the phonological systems. While language variation is constantly occurring, it is the interaction of all these factors that pave the way for change in a certain direction. A set of changes occur due to these factors and result in what we identify as areal linguistic features. Thus, areal features may be understood to be *emergent* from the ecosystem of shared social factors and languages.

In the case of Kuy, the register contrast is mediated by the usage of the four languages of the area, two of which are non-tonal and two of which are tonal. In recent times, the social situation has tipped the scales in favor of greater usage of Thai, which can lead to a greater effect of the Thai phonological system on the Kuy register contrast. Resulting from this is the potential change of tonogenesis. In conjunction with other changes we see occurring in Kuy, such as monosyllabization (from the loss of the syllabic nasal), we see the emergence of canonical Mainland Southeast Asian language features.

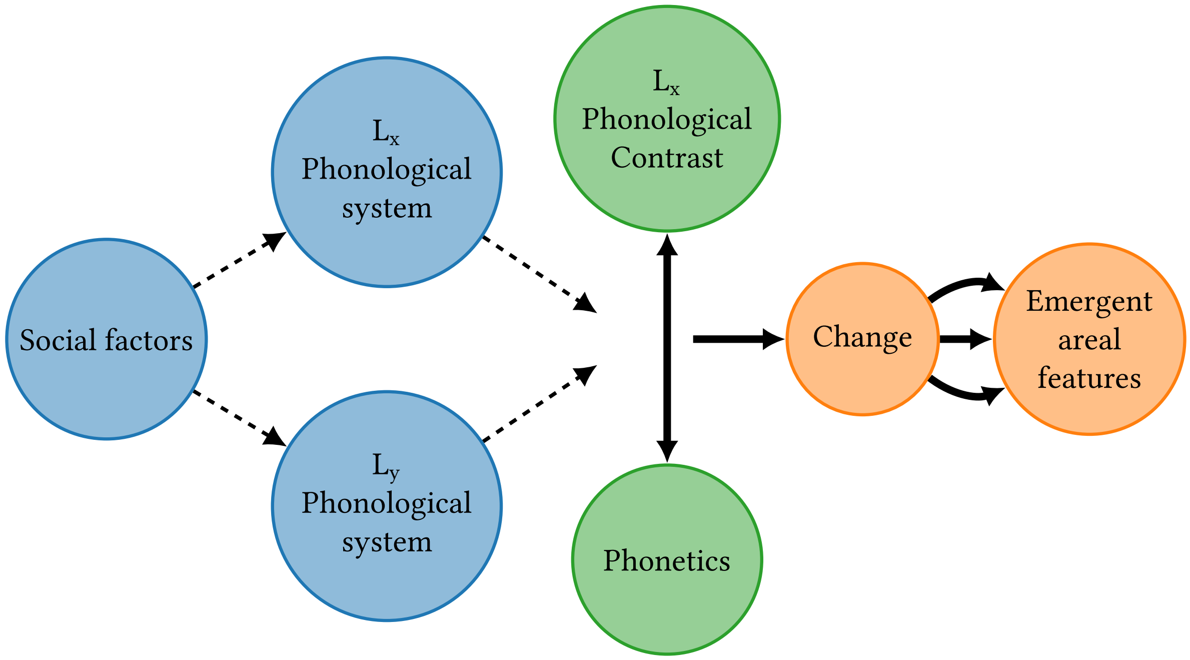


Figure 6.1: Schema of multiple mechanisms effecting language change

Given the long co-existence of Kuy with other groups and extended period of quadrilingualism, one might wonder why such changes did not happen in the past. While I do not have a clear explanation for this, I can speculate that it is due to the changing nature of the quadrilingualism. Even if Kuy speakers have had knowledge of all four languages for centuries, they have not always used them all to equal extents. Given the long historical overlap of Kuy and Khmer territories, it was likely that Khmer was the most influential non-Kuy language for a time, particularly during the period of the Khmer Empire. As Khmer was not tonal, there would not have been a bias towards usage of f0 cues; rather, Khmer has been suggested as the source of initial devoicing, registrogenesis, and vowel restructuring in West Katuic languages (Diffloth, 1982, Gehrmann, 2016, iii). As dynamics shifted, Lao became a more dominating presence as Kuy territory became part of the Lan Xang Kingdom. Why register did not give way to tone during that time could be chance, as sound change is of course not deterministic, but could also be related to how centralized the kingdom was. Næss and Jenny (2011, 230) point out that features of Mon spread into the speech of monolingual Burmese speakers in southern Burma, but not into that of monolingual Thai speakers in Central Thailand, despite the similar status of Mon in the two areas for at least three centuries. They attribute the lack of parallelism to the higher level of centralization and standardization in Thailand. If the Kuy area was not particularly incorporated into Lan Xang, the usage of Lao may not have been enough to precipitate change. A deeper understanding of the social dynamics and extent of Lao usage at the time would be key to understanding this part of the puzzle. In the present day, however, the effects of Thailand's centralization policies are very clear, with schools playing a prominent role in the process and tipping the scales of multilingualism in favor of Thai through codification and ubiquity.

Crucially, the signaling of register with phonation is still robust in almost all speakers in perception and most speakers in production—I make no claim that tonogenesis has occurred nor that it necessarily will occur. Rather, the key result from this study is that the usage of a tonal language has the potential to act as a *catalyst* for tonogenesis. The shift in cue usage due to knowledge of another language aligns with previous literature on bilinguals' differing cue usage in both their L1 and L2. 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. While 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 multilingual 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 (2015a) in suggesting that preexisting f0 differences in register are *enhanced* through the shared cue usage, thus making Kuy more "tone-prone". This enhancement shifts the distribution of f0 cue weights in Kuy, and while it does not necessitate the contrast to transform into a tonal one, the distancing of f0 modal and breathy distributions may cause listeners to be more likely to identify f0 as a meaningful cue, subsequently increasing the probability of tonogenesis occurring.

In this dissertation, I attempted to flesh out the path from shifting social situations to sound change. 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 more recent social pressures and changes in the life trajectory of an average Kuy person that are forces in the transition towards increased usage of Thai by individual members of the community. These shifts redefine the linguistic landscape by creating an environment in which the default language of use in the Kuy community is no longer just Kuy, but includes Thai. The fact that many young parents use Thai with their children even suggests that the default language may be trending towards only Thai. With the usage of Thai in everyday life becoming a social norm, members of the community increasingly become used to switching between Kuy and Thai on a daily basis. On a mechanical level, the continual switching between two different languages can bring about changes and potential gradual convergence in articulatory routines. The increased exposure to another language in everyday life can also influence the relative importance of different cues in language perception. The studies carried out in this dissertation looked at how individual variation in language experience could lead to different patterns in the realization of a phonological contrast. These results were analyzed against the background of community-level societal changes as well as existing structural factors in the language.

The findings leave open a wealth of questions that still need to be explored and better understood. For example, the role of other register cues, such as F1, must be better understood, particularly as F1 was a reliable voice quality cue in production for much of the population. Another important topic to be investigated is the social networks of individual members of the Kuy community, which must be diagrammed in greater detail to test whether the idea that the lack of a relationship between language experience and the usage of f0 cues in male speakers in production is related to tighter Kuy social networks holds weight or not. Language experience was also only roughly approximated and a more in-depth study of how to quantify it would also lead to a better understanding of the dimensions that capture language experience well and subsequently, more precise interpretations of results. Yet another large topic that was left unexplored in this dissertation was the discernment of the roles of listeners and speakers in sound change; while the behavior of listeners and speakers was analyzed, the connection between these behaviors and sound change remains to be examined. Finally of course, since this is just one case study with one Kuy population, it is imperative to observe the effects of these factors in similar situations both in other Kuy populations and crosslinguistically in other similar multilingual settings. Through investigating the complicated interplay between macro-level language contact, micro-level individual patterns of multilingualism, and their effects on the phonetic realizations of a phonological contrast, this study has shown how the rich variation in the community offers insights into the mechanisms by which societal change leads to transitioning behaviors of language usage and can translate into cue shifts that lay the groundwork for sound change.

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Appendix A

Demographic Questionnaire (English)

Demographic Questionnaire

Location ....

Date.............Month.....................Year ....

Subject Number ....

Age ....

Gender...................

Occupation ....

1. From what age did you start feeling comfortable speaking the following languages?

Kuy ....**Thai** ....**Lao** ....**Khmer** ....

2a. Please rank the following languages by order of how often you speak them (1 = most often)

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

2b. What percentage of the time do you speak each of the following languages:

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

3. How well do you understand the following languages? Please check ✓ the appropriate box)

Kuy	**Thai**	**Lao**	**Khmer**
☐ Not at all	☐ Not at all	☐ Not at all	☐ Not at all
☐ A little	☐ A little	☐ A little	☐ A little
☐ Somewhat	☐ Somewhat	☐ Somewhat	☐ Somewhat
☐ Mostly	☐ Mostly	☐ Mostly	☐ Mostly
☐ Fully	☐ Fully	☐ Fully	☐ Fully

Other than Kuy, Thai, Lao, and Khmer, what other languages do you know?

....

4. How well do you speak the following languages? (Please check ✓ the appropriate box)

Kuy	Thai	Lao	Khmer
☐ Not at all	☐ Not at all	☐ Not at all	☐ Not at all
☐ Not well	☐ Not well	☐ Not well	☐ Not well
☐ Average	☐ Average	☐ Average	☐ Average
☐ Fairly well	☐ Fairly well	☐ Fairly well	☐ Fairly well
☐ Very well	☐ Very well	☐ Very well	☐ Very well

5a. Please rank the following languages by order of how often you speak them with family (1 = most often)

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

5b. What percentage of the time do you speak each of the following languages with family:

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

6a. Please rank the following languages by order of how often you speak them with friends (1 = most often)

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

6b. What percentage of the time do you speak each of the following languages with friends:

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

7a. Please rank the following groups by how strongly you identify with them (1 = most strongly)

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

7b. How strongly do you identify with the following groups? (Please check ✓ the appropriate box)

Kuy	Thai	Lao	Khmer
☐ Not at all	☐ Not at all	☐ Not at all	☐ Not at all
☐ Barely	☐ Barely	☐ Barely	☐ Barely
☐ Somewhat	☐ Somewhat	☐ Somewhat	☐ Somewhat
☐ Very much	☐ Very much	☐ Very much	☐ Very much

8. What language do you count in? ____________________

9. How often do you write in Kuy?

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ All the time

10. If someone speaks to you in each of the following languages, what language would you feel most comfortable responding in?

Kuy .... **Thai** .... **Lao** .... **Khmer** ....

11. Please list the family members you live with and the language(s) you speak with them

Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....

12. Who are the 5 people you speak with most and the language(s) you speak with them?

Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....
Relationship: .... Languages ....

13. Please list the places you have lived and the length of time you have spent in each place.

Place .... Time spent: Month ...... Year.......... Until Month ...... Year ....

Place .... Time spent: Month ...... Year.......... Until Month ...... Year ....

Place .... Time spent: Month ...... Year.......... Until Month ...... Year ....

Place .... Time spent: Month ...... Year.......... Until Month ...... Year ....

Place .... Time spent: Month ...... Year.......... Until Month ...... Year ....

Place .... Time spent: Month ...... Year.......... Until Month ...... Year ....

14. Educational history

Primary School

School .... From Grade ...... until Grade ....

School .... From Grade ...... until Grade ....

Secondary School

School .... From Grade ...... until Grade ....

School .... From Grade ...... until Grade ....

University .... from Year ...... until Year ....

Appendix B

Wordlist and counts for production study

The target words and distractor tokens for the production study are presented in Tables B.1 and B.2. Parentheses indicate segments that may or may not be realized and that cannot be phonologically derived. The distribution of onsets, nuclei, and codas in the target words are presented in Tables B.3, B.4, and B.5, respectively.

[1]In general, older speakers rarely drop the syllabic nasal; however, the syllabic nasal in this word only surfaces in 13 speakers, 9 of whom are between 20 and 40 and 4 of whom are between 50 and 70. It is unusual that more younger speakers realize the syllabic nasal in this word than older speakers do, but the syllabic nasal is indeed attested in the Kuy varieties in Sriwises (1978, 397) and Gehrmann (2016, 315). Sidwell (2005, 130) reconstructs this word in Proto-Katuic as *-gɛːŋ (the hyphen appears to represent uncertainty about the consonant in the sesquisyllable due to the variety of consonants in the daughter languages) and derives "prenasalization" (syllabic nasals) from *ʔn in the sesquisyllable Sidwell (2005, 32). As Sidwell doesn't reconstruct the proto-form with *ʔn and younger speakers drop the syllabic nasal *less*, it is possible that the syllabic nasal is not original.

[2]This word may be realized as [sn̩teː], [n̩teː], or [teː]. Theoretically, [steː] should also be possible, as other words with an onset and syllabic nasal in the first syllable of a sesquisyllabic word often show dropping of just the syllabic nasal, but this form was not produced by any of the participants in this study.

Table B.1: Target words

Comparison	Word	Gloss
unaspirated modal vs. breathy	ŋkɛ:ŋ	‘waist’
	(ŋ)kɛ̤:ŋ[1]	‘side’
	ku:	‘to exist’
	kṳ:	‘every’
	pi:r	‘flower’
	pi̤:r	‘to wind’
	po:t	‘swelling’
	po̤:t	‘too much’
	pu:ʔ	‘sun’
	pṳ:ʔ	‘beard’
	taʔ	‘to grab (from above)’
	ta̤ʔ	‘to place under’
	tah	‘to divorce’
	ta̤h	‘to slap’
	ti:	‘old’
	ti̤:	‘tall’
	to:ŋ	‘coconut’
	to̤:ŋ	‘male (animal)’
	t(ia̤ŋ)pat	‘west’
	tpa̤t	‘six’
aspirated modal vs. breathy	n̩cʰu:n	‘to hide’
	cṳ:n	‘to send’
	pʰo:m	‘fragrant’
	m̩po̤:m	‘just (now)’
unaspirated modal vs. aspirated modal vs. breathy	(s)n̩te:[2]	‘to tell’
	tʰe:	‘jar’
	te̤:	‘no’
sonorant modal vs. sonorant breathy	lɑp	‘to return’
	lɑ̤p (la̤p)	‘dusk’
	lu:	‘to howl’
	lṳ:	‘thigh’

Table B.2: Production experiment distractor tokens

Distractors	Gloss	Prenasalization	/tr/ cluster	Final /r/
buʔ	‘to sow’			
n̩cɛ:	‘louse’	✓		
n̩cʰɑ:ʔ	‘hay’	✓		
n̩cʰɔʔ	‘smelly’	✓		
cn̩trʌ̤ŋ	‘diligent’	✓	✓	
cɤ̤:l	‘tiger’			
da̤h	‘to bite (and break)’			
daʔ	‘to place’			
kʰal	‘scooping bowl’			
kʌ̤l	‘tree’			
kʰo:kʰo:	‘toasted rice’			
ko̤:	‘cow’			
ktɤ:	‘season’			
ŋkʌŋ	‘eggplant’	✓		
lm̩pa:ʔ	‘shoulder’	✓		
m̩pe̤:ʔ	‘mother’			
pʰ(at)lɯ:m	‘lightning’	✓		
rm̩pa̤t	‘stick’	✓		
sɛh	‘horse’			
sʌ:ŋ	‘five’			
sŋki:l	‘sensitive’	✓		✓
tm̩po:m	‘that which is wrapped’	✓		
n̩tɔ:l	‘star’	✓		
n̩trɑ:ŋ	‘red ant’	✓	✓	
tʰrɛ:	‘rice paddy’		✓	
n̩trɛ̤:l	‘egg’	✓	✓	
n̩tri̤:m	‘shovel’	✓	✓	

[2]This word may be realized as [cn̩trʌ̤ŋ], [ctrʌ̤ŋ], or [n̩trʌ̤ŋ]. [trʌ̤ŋ] was not observed in any of the participants.

Table B.3: Onset counts by unique word

Onset	Comparison	Count	Potential minor syllables
t	unaspirated modal vs. breathy	8	1 pair: /tpat/ ∼ /tpa̤t/ pair
	unaspirated modal vs. aspirated modal vs. breathy	3	1 word: /n̩te/
p	unaspirated modal vs. breathy	8	
	aspirated modal vs. breathy	2	1 word: /m̩po̤:m/
k	unaspirated modal vs. breathy	4	1 pair: /ŋkɛ:ŋ/ ∼ /(ŋ)kɛ̤:ŋ/
c	aspirated modal vs. breathy	2	1 word: /n̩cʰu:n/
l	modal vs. breathy	4	

Table B.4: Nucleus counts by unique word

Vowel	Count
u:	8
o:	6
a	6
i:	4
e:	3
ɛ:	2
ɑ	2

Table B.5: Coda counts by unique word

Coda	Count
∅	7
ŋ	6
t	4
ʔ	4
m	2
n	2
h	2
p	2
l	2

Appendix C

Linear regression tables for production study

Table C.1: Estimates for f0 (semitones) linear regression model

	Est.	SE	t	df	p		Est.	SE	t	df	p
(Intercept)	-.12	.05	-2.35	3.34E+01	.025	Time1:GenderM:TLE	-.25	.09	-2.81	1.02E+05	.005
Time1	-.56	.03	-19.56	1.02E+05	< .001	Time2:GenderM:TLE	-.22	.06	-3.63	1.02E+05	< .001
Time2	.53	.02	26.99	1.02E+05	< .001	Time3:GenderM:TLE	-.59	.04	-13.14	1.02E+05	< .001
Time3	-.10	.01	-7.06	1.02E+05	< .001	RegisterModal:GenderM:TLE	-.57	.04	-13.85	1.02E+05	< .001
RegisterModal	.33	.07	4.89	3.35E+01	< .001	Time1:RegisterModal:Away	.07	.08	.81	1.02E+05	.421
GenderM	.00	.01	.28	1.02E+05	.779	Time2:RegisterModal:Away	-.06	.06	-1.07	1.02E+05	.285
TLE	-.12	.02	-6.35	1.02E+05	< .001	Time3:RegisterModal:Away	-.08	.04	-1.80	1.02E+05	.072
Away	-.10	.02	-5.06	1.02E+05	< .001	Time1:GenderM:Away	-.08	.09	-.88	1.02E+05	.381
Time1:RegisterModal	.44	.04	11.07	1.02E+05	< .001	Time2:GenderM:Away	.08	.06	1.23	1.02E+05	.218
Time2:RegisterModal	-.30	.03	-1.71	1.02E+05	< .001	Time3:GenderM:Away	.28	.05	6.13	1.02E+05	< .001
Time3:RegisterModal	-.30	.02	-14.74	1.02E+05	< .001	RegisterModal:GenderM:Away	.11	.04	2.55	1.02E+05	.011
Time1:GenderM	.20	.04	5.11	1.02E+05	< .001	Time1:TLE:Away	-.40	.11	-3.73	1.02E+05	< .001
Time2:GenderM	-.16	.03	-5.84	1.02E+05	< .001	Time2:TLE:Away	-.41	.07	-5.53	1.02E+05	< .001
Time3:GenderM	-.01	.02	-.30	1.02E+05	.768	Time3:TLE:Away	-.11	.06	-2.04	1.02E+05	.041
RegisterModal:GenderM	.04	.02	2.34	1.02E+05	.020	RegisterModal:TLE:Away	-.23	.05	-4.57	1.02E+05	< .001
Time1:TLE	-.04	.06	-.64	1.02E+05	.519	GenderM:TLE:Away	-.67	.06	-1.52	1.02E+05	< .001
Time2:TLE	-.16	.04	-4.03	1.02E+05	< .001	Time1:RegisterModal:GenderM:TLE	.53	.12	4.36	1.02E+05	< .001
Time3:TLE	.17	.03	5.51	1.02E+05	< .001	Time2:RegisterModal:GenderM:TLE	.38	.08	4.45	1.02E+05	< .001
RegisterModal:TLE	.19	.03	7.03	1.02E+05	< .001	Time3:RegisterModal:GenderM:TLE	.57	.06	9.00	1.02E+05	< .001
GenderM:TLE	.39	.03	13.10	1.02E+05	< .001	Time1:RegisterModal:GenderM:Away	-.25	.13	-1.95	1.02E+05	.051
Time1:Away	.08	.06	1.38	1.02E+05	.167	Time2:RegisterModal:GenderM:Away	-.05	.09	-.54	1.02E+05	.592
Time2:Away	.28	.04	6.82	1.02E+05	< .001	Time3:RegisterModal:GenderM:Away	-.08	.07	-1.20	1.02E+05	.231
Time3:Away	.03	.03	1.14	1.02E+05	.255	Time1:RegisterModal:TLE:Away	.25	.15	1.64	1.02E+05	.101
RegisterModal:Away	.04	.03	1.46	1.02E+05	.144	Time2:RegisterModal:TLE:Away	.25	.10	2.36	1.02E+05	.018
GenderM:Away	-.06	.03	-2.13	1.02E+05	.033	Time3:RegisterModal:TLE:Away	.26	.08	3.39	1.02E+05	< .001
TLE:Away	.26	.04	7.23	1.02E+05	< .001	Time1:GenderM:TLE:Away	.50	.19	2.67	1.02E+05	.008
Time1:RegisterModal:GenderM	-.21	.06	-3.72	1.02E+05	< .001	Time2:GenderM:TLE:Away	1.51	.13	11.56	1.02E+05	< .001
Time2:RegisterModal:GenderM	-.05	.04	-1.35	1.02E+05	.178	Time3:GenderM:TLE:Away	.81	.10	8.33	1.02E+05	< .001
Time3:RegisterModal:GenderM	-.01	.03	-.45	1.02E+05	.653	RegisterModal:GenderM:TLE:Away	.56	.09	6.17	1.02E+05	< .001
Time1:RegisterModal:TLE	.04	.08	.44	1.02E+05	.658	Time1:RegisterModal:GenderM:TLE:Away	-.65	.27	-2.41	1.02E+05	.016
Time2:RegisterModal:TLE	.06	.06	1.14	1.02E+05	.254	Time2:RegisterModal:GenderM:TLE:Away	-.84	.19	-4.56	1.02E+05	< .001
Time3:RegisterModal:TLE	-.03	.04	-.62	1.02E+05	.536	Time3:RegisterModal:GenderM:TLE:Away	-.77	.14	-5.60	1.02E+05	< .001

Table C.2: Estimates for $H_1{}^*(-H_2{}^*)$ linear regression model

	Est.	SE	t	df	p		Est.	SE	t	df	p
(Intercept)	.12	.04	2.99	3.51E+01	.005	Time1:GenderM:TLE	-.71	.09	-7.95	1.02E+05	< .001
Time1	-.04	.03	-1.42	1.02E+05	.156	Time2:GenderM:TLE	.02	.06	.34	1.02E+05	.737
Time2	-.12	.02	-5.73	1.02E+05	< .001	Time3:GenderM:TLE	-.42	.05	-9.09	1.02E+05	< .001
Time3	-.06	.02	-4.12	1.02E+05	< .001	RegisterModal:GenderM:TLE	-.56	.04	-13.02	1.02E+05	< .001
RegisterModal	-.28	.06	-5.01	3.51E+01	< .001	Time1:RegisterModal:Away	.04	.08	.46	1.02E+05	.649
GenderM	.54	.01	39.77	1.02E+05	< .001	Time2:RegisterModal:Away	.00	.06	.00	1.02E+05	.998
TLE	-.33	.02	-16.11	1.02E+05	< .001	Time3:RegisterModal:Away	.00	.04	.04	1.02E+05	.969
Away	.03	.02	1.23	1.02E+05	.219	Time1:GenderM:Away	.32	.09	3.44	1.02E+05	< .001
Time1:RegisterModal	.01	.04	.34	1.02E+05	.734	Time2:GenderM:Away	-.03	.06	-.55	1.02E+05	.585
Time2:RegisterModal	.37	.03	12.80	1.02E+05	< .001	Time3:GenderM:Away	-.13	.05	-2.63	1.02E+05	.008
Time3:RegisterModal	.19	.02	8.74	1.02E+05	< .001	RegisterModal:GenderM:Away	-.01	.04	-.32	1.02E+05	.751
Time1:GenderM	-.66	.04	-16.34	1.02E+05	< .001	Time1:TLE:Away	-.01	.11	-.11	1.02E+05	.912
Time2:GenderM	-.47	.03	-16.79	1.02E+05	< .001	Time2:TLE:Away	.18	.08	2.35	1.02E+05	.019
Time3:GenderM	-.60	.02	-28.64	1.02E+05	< .001	Time3:TLE:Away	.11	.06	2.00	1.02E+05	.045
RegisterModal:GenderM	-.39	.02	-2.09	1.02E+05	< .001	RegisterModal:TLE:Away	.33	.05	6.37	1.02E+05	< .001
Time1:TLE	.49	.06	8.18	1.02E+05	< .001	GenderM:TLE:Away	.08	.07	1.26	1.02E+05	.207
Time2:TLE	.14	.04	3.31	1.02E+05	< .001	Time1:RegisterModal:GenderM:TLE	.34	.13	2.65	1.02E+05	.008
Time3:TLE	.41	.03	13.29	1.02E+05	< .001	Time2:RegisterModal:GenderM:TLE	.29	.09	3.28	1.02E+05	.001
RegisterModal:TLE	.25	.03	8.72	1.02E+05	< .001	Time3:RegisterModal:GenderM:TLE	.29	.07	4.40	1.02E+05	< .001
GenderM:TLE	.44	.03	14.36	1.02E+05	< .001	Time1:RegisterModal:GenderM:Away	-.27	.13	-2.10	1.02E+05	.035
Time1:Away	-.12	.06	-1.94	1.02E+05	.052	Time2:RegisterModal:GenderM:Away	-.01	.09	-.09	1.02E+05	.927
Time2:Away	-.06	.04	-1.36	1.02E+05	.172	Time3:RegisterModal:GenderM:Away	.04	.07	.53	1.02E+05	.595
Time3:Away	-.02	.03	-.64	1.02E+05	.524	Time1:RegisterModal:TLE:Away	-.48	.15	-3.10	1.02E+05	.002
RegisterModal:Away	.04	.03	1.34	1.02E+05	.179	Time2:RegisterModal:TLE:Away	-.16	.11	-1.47	1.02E+05	.141
GenderM:Away	.00	.03	.15	1.02E+05	.884	Time3:RegisterModal:TLE:Away	-.28	.08	-3.50	1.02E+05	< .001
TLE:Away	-.13	.04	-3.41	1.02E+05	< .001	Time1:GenderM:TLE:Away	.58	.19	2.97	1.02E+05	.003
Time1:RegisterModal:GenderM	.16	.06	2.86	1.02E+05	.004	Time2:GenderM:TLE:Away	-.34	.13	-2.54	1.02E+05	.011
Time2:RegisterModal:GenderM	.12	.04	3.13	1.02E+05	.002	Time3:GenderM:TLE:Away	-.38	.10	-3.82	1.02E+05	< .001
Time3:RegisterModal:GenderM	.29	.03	9.86	1.02E+05	< .001	RegisterModal:GenderM:TLE:Away	-.07	.09	-.73	1.02E+05	.464
Time1:RegisterModal:TLE	-.15	.08	-1.83	1.02E+05	.068	Time1:RegisterModal:GenderM:TLE:Away	-.28	.28	-1.01	1.02E+05	.311
Time2:RegisterModal:TLE	-.25	.06	-4.32	1.02E+05	< .001	Time2:RegisterModal:GenderM:TLE:Away	.28	.19	1.44	1.02E+05	.149
Time3:RegisterModal:TLE	-.13	.04	-2.91	1.02E+05	.004	Time3:RegisterModal:GenderM:TLE:Away	.09	.14	.65	1.02E+05	.513

Table C.3: Estimates for $H_1{}^*(-A_\mathrm{n}{}^*)$ linear regression model

	Est.	SE	t	df	p		Est.	SE	t	df	p
(Intercept)	.20	.08	2.42	3.14E+01	.022	Time1:GenderM:TLE	-.28	.06	-4.51	1.02E+05	< .001
Time1	.23	.02	11.59	1.02E+05	< .001	Time2:GenderM:TLE	.09	.04	2.16	1.02E+05	.031
Time2	-.32	.01	-23.11	1.02E+05	< .001	Time3:GenderM:TLE	.11	.03	3.43	1.02E+05	< .001
Time3	-.18	.01	-17.17	1.02E+05	< .001	RegisterModal:GenderM:TLE	-.21	.03	-7.17	1.02E+05	< .001
RegisterModal	-.39	.12	-3.35	3.14E+01	.002	Time1:RegisterModal:Away	-.08	.06	-1.31	1.02E+05	.190
GenderM	.11	.01	12.00	1.02E+05	< .001	Time2:RegisterModal:Away	-.04	.04	-1.09	1.02E+05	.277
TLE	-.13	.01	-9.34	1.02E+05	< .001	Time3:RegisterModal:Away	.00	.03	.10	1.02E+05	.923
Away	-.05	.01	-3.43	1.02E+05	< .001	Time1:GenderM:Away	.14	.06	2.28	1.02E+05	.023
Time1:RegisterModal	-.13	.03	-4.56	1.02E+05	< .001	Time2:GenderM:Away	.03	.04	.78	1.02E+05	.436
Time2:RegisterModal	.31	.02	15.90	1.02E+05	< .001	Time3:GenderM:Away	-.16	.03	-4.89	1.02E+05	< .001
Time3:RegisterModal	.29	.01	19.93	1.02E+05	< .001	RegisterModal:GenderM:Away	.08	.03	2.68	1.02E+05	.007
Time1:GenderM	-.15	.03	-5.29	1.02E+05	< .001	Time1:TLE:Away	.14	.07	1.92	1.02E+05	.054
Time2:GenderM	-.13	.02	-6.91	1.02E+05	< .001	Time2:TLE:Away	.30	.05	5.79	1.02E+05	< .001
Time3:GenderM	-.05	.01	-3.82	1.02E+05	< .001	Time3:TLE:Away	.15	.04	3.91	1.02E+05	< .001
RegisterModal:GenderM	-.09	.01	-6.71	1.02E+05	< .001	RegisterModal:TLE:Away	.23	.04	6.50	1.02E+05	< .001
Time1:TLE	.25	.04	6.16	1.02E+05	< .001	GenderM:TLE:Away	.05	.04	1.21	1.02E+05	.225
Time2:TLE	.11	.03	3.97	1.02E+05	< .001	Time1:RegisterModal:GenderM:TLE	.17	.09	1.97	1.02E+05	.048
Time3:TLE	.11	.02	5.12	1.02E+05	< .001	Time2:RegisterModal:GenderM:TLE	.02	.06	.32	1.02E+05	.751
RegisterModal:TLE	.15	.02	7.64	1.02E+05	< .001	Time3:RegisterModal:GenderM:TLE	.06	.04	1.46	1.02E+05	.145
GenderM:TLE	.10	.02	5.03	1.02E+05	< .001	Time1:RegisterModal:GenderM:Away	-.10	.09	-1.08	1.02E+05	.282
Time1:Away	.04	.04	.97	1.02E+05	.331	Time2:RegisterModal:GenderM:Away	-.03	.06	-.41	1.02E+05	.678
Time2:Away	-.01	.03	-.38	1.02E+05	.704	Time3:RegisterModal:GenderM:Away	-.01	.05	-.26	1.02E+05	.793
Time3:Away	.05	.02	2.56	1.02E+05	.010	Time1:RegisterModal:TLE:Away	-.14	.11	-1.32	1.02E+05	.187
RegisterModal:Away	.04	.02	2.00	1.02E+05	.046	Time2:RegisterModal:TLE:Away	-.18	.07	-2.48	1.02E+05	.013
GenderM:Away	-.04	.02	-1.68	1.02E+05	.094	Time3:RegisterModal:TLE:Away	-.24	.05	-4.44	1.02E+05	< .001
TLE:Away	-.20	.03	-7.76	1.02E+05	< .001	Time1:GenderM:TLE:Away	.23	.13	1.76	1.02E+05	.078
Time1:RegisterModal:GenderM	.05	.04	1.32	1.02E+05	.188	Time2:GenderM:TLE:Away	-.54	.09	-5.87	1.02E+05	< .001
Time2:RegisterModal:GenderM	.01	.03	.38	1.02E+05	.705	Time3:GenderM:TLE:Away	-.46	.07	-6.70	1.02E+05	< .001
Time3:RegisterModal:GenderM	.03	.02	1.40	1.02E+05	.160	RegisterModal:GenderM:TLE:Away	-.03	.06	-.52	1.02E+05	.602
Time1:RegisterModal:TLE	-.05	.06	-.86	1.02E+05	.392	Time1:RegisterModal:GenderM:TLE:Away	-.27	.19	-1.44	1.02E+05	.150
Time2:RegisterModal:TLE	-.09	.04	-2.33	1.02E+05	.020	Time2:RegisterModal:GenderM:TLE:Away	.35	.13	2.70	1.02E+05	.007
Time3:RegisterModal:TLE	-.09	.03	-3.23	1.02E+05	.001	Time3:RegisterModal:GenderM:TLE:Away	.26	.10	2.74	1.02E+05	.006

Table C.4: Estimates for CPP linear regression model

	Est.	SE	t	df	p		Est.	SE	t	df	p
(Intercept)	-.79	.05	-16.19	3.29E+01	< .001	Time1:GenderM:TLE	.36	.08	4.68	1.02E+05	< .001
Time1	1.44	.03	57.19	1.02E+05	< .001	Time2:GenderM:TLE	.08	.05	1.58	1.02E+05	.113
Time2	.88	.02	5.78	1.02E+05	< .001	Time3:GenderM:TLE	-.05	.04	-1.18	1.02E+05	.239
Time3	.64	.01	49.32	1.02E+05	< .001	RegisterModal:GenderM:TLE	.18	.04	4.92	1.02E+05	< .001
RegisterModal	.25	.07	3.70	3.29E+01	< .001	Time1:RegisterModal:Away	.13	.07	1.80	1.02E+05	.072
GenderM	.00	.01	.07	1.02E+05	.946	Time2:RegisterModal:Away	-.03	.05	-.62	1.02E+05	.537
TLE	.00	.02	-.08	1.02E+05	.936	Time3:RegisterModal:Away	-.08	.04	-2.23	1.02E+05	.026
Away	-.01	.02	-.54	1.02E+05	.591	Time1:GenderM:Away	-.21	.08	-2.60	1.02E+05	.009
Time1:RegisterModal	.02	.04	.45	1.02E+05	.656	Time2:GenderM:Away	-.01	.05	-.26	1.02E+05	.798
Time2:RegisterModal	-.05	.02	-2.25	1.02E+05	.025	Time3:GenderM:Away	.00	.04	-.02	1.02E+05	.986
Time3:RegisterModal	-.16	.02	-8.88	1.02E+05	< .001	RegisterModal:GenderM:Away	-.10	.04	-2.57	1.02E+05	.010
Time1:GenderM	-.03	.03	-.97	1.02E+05	.331	Time1:TLE:Away	-.33	.09	-3.52	1.02E+05	< .001
Time2:GenderM	.12	.02	4.96	1.02E+05	< .001	Time2:TLE:Away	.14	.07	2.12	1.02E+05	.034
Time3:GenderM	.00	.02	-.25	1.02E+05	.799	Time3:TLE:Away	-.06	.05	-1.18	1.02E+05	.238
RegisterModal:GenderM	-.08	.02	-4.71	1.02E+05	< .001	RegisterModal:TLE:Away	.03	.04	.75	1.02E+05	.456
Time1:TLE	-.25	.05	-4.90	1.02E+05	< .001	GenderM:TLE:Away	-.04	.06	-.77	1.02E+05	.442
Time2:TLE	-.12	.04	-3.46	1.02E+05	< .001	Time1:RegisterModal:GenderM:TLE	-.69	.11	-6.38	1.02E+05	< .001
Time3:TLE	.16	.03	5.95	1.02E+05	< .001	Time2:RegisterModal:GenderM:TLE	.05	.07	.62	1.02E+05	.537
RegisterModal:TLE	-.01	.02	-.26	1.02E+05	.795	Time3:RegisterModal:GenderM:TLE	-.08	.06	-1.37	1.02E+05	.170
GenderM:TLE	-.11	.03	-4.23	1.02E+05	< .001	Time1:RegisterModal:GenderM:Away	.06	.11	.54	1.02E+05	.587
Time1:Away	.01	.05	.19	1.02E+05	.853	Time2:RegisterModal:GenderM:Away	.20	.08	2.55	1.02E+05	.011
Time2:Away	.11	.04	2.95	1.02E+05	.003	Time3:RegisterModal:GenderM:Away	.09	.06	1.61	1.02E+05	.108
Time3:Away	.02	.03	.76	1.02E+05	.445	Time1:RegisterModal:TLE:Away	.15	.13	1.12	1.02E+05	.264
RegisterModal:Away	-.04	.02	-1.67	1.02E+05	.094	Time2:RegisterModal:TLE:Away	-.40	.09	-4.43	1.02E+05	< .001
GenderM:Away	.05	.03	1.69	1.02E+05	.091	Time3:RegisterModal:TLE:Away	-.16	.07	-2.30	1.02E+05	.022
TLE:Away	.09	.03	2.87	1.02E+05	.004	Time1:GenderM:TLE:Away	.14	.17	.83	1.02E+05	.405
Time1:RegisterModal:GenderM	-.01	.05	-.17	1.02E+05	.866	Time2:GenderM:TLE:Away	.00	.12	-.02	1.02E+05	.988
Time2:RegisterModal:GenderM	.11	.03	3.14	1.02E+05	.002	Time3:GenderM:TLE:Away	.18	.09	2.16	1.02E+05	.031
Time3:RegisterModal:GenderM	.05	.03	2.18	1.02E+05	.029	RegisterModal:GenderM:TLE:Away	-.36	.08	-4.58	1.02E+05	< .001
Time1:RegisterModal:TLE	.51	.07	7.17	1.02E+05	< .001	Time1:RegisterModal:GenderM:TLE:Away	.33	.24	1.42	1.02E+05	.156
Time2:RegisterModal:TLE	-.11	.05	-2.32	1.02E+05	.020	Time2:RegisterModal:GenderM:TLE:Away	.55	.16	3.41	1.02E+05	< .001
Time3:RegisterModal:TLE	.00	.04	-.03	1.02E+05	.972	Time3:RegisterModal:GenderM:TLE:Away	.31	.12	2.54	1.02E+05	.011

Table C.5: Estimates for F1 (semitones) linear regression model

	Est.	*SE*	*t*	df	*p*		Est.	*SE*	*t*	df	*p*
(Intercept)	-.45	.05	-8.90	3.32E+01	< .001	Time1:GenderM:TLE	-.83	.09	-9.41	1.02E+05	< .001
Time1	.24	.03	8.36	1.02E+05	< .001	Time2:GenderM:TLE	-.43	.06	-7.01	1.02E+05	< .001
Time2	.12	.02	6.17	1.02E+05	< .001	Time3:GenderM:TLE	-.63	.05	-13.92	1.02E+05	< .001
Time3	.59	.01	39.59	1.02E+05	< .001	RegisterModal:GenderM:TLE	-.50	.04	-11.79	1.02E+05	< .001
RegisterModal	.66	.07	9.25	3.32E+01	< .001	Time1:RegisterModal:Away	-.09	.08	-1.04	1.02E+05	.299
GenderM	.02	.01	1.37	1.02E+05	.172	Time2:RegisterModal:Away	-.11	.06	-1.92	1.02E+05	.055
TLE	-.24	.02	-11.84	1.02E+05	< .001	Time3:RegisterModal:Away	-.08	.04	-1.92	1.02E+05	.055
Away	-.06	.02	-3.00	1.02E+05	.003	Time1:GenderM:Away	.28	.09	3.12	1.02E+05	.002
Time1:RegisterModal	-.38	.04	-9.44	1.02E+05	< .001	Time2:GenderM:Away	-.19	.06	-3.01	1.02E+05	.003
Time2:RegisterModal	-.46	.03	-16.26	1.02E+05	< .001	Time3:GenderM:Away	.04	.05	.77	1.02E+05	.442
Time3:RegisterModal	-.48	.02	-22.79	1.02E+05	< .001	RegisterModal:GenderM:Away	.07	.04	1.68	1.02E+05	.093
Time1:GenderM	.08	.04	1.91	1.02E+05	.056	Time1:TLE:Away	-.05	.11	-.42	1.02E+05	.675
Time2:GenderM	-.04	.03	-1.49	1.02E+05	.137	Time2:TLE:Away	.32	.08	4.22	1.02E+05	< .001
Time3:GenderM	-.09	.02	-4.28	1.02E+05	< .001	Time3:TLE:Away	-.06	.06	-1.04	1.02E+05	.300
RegisterModal:GenderM	-.14	.02	-7.31	1.02E+05	< .001	RegisterModal:TLE:Away	.07	.05	1.40	1.02E+05	.160
Time1:TLE	.37	.06	6.24	1.02E+05	< .001	GenderM:TLE:Away	-.51	.06	-7.82	1.02E+05	< .001
Time2:TLE	.20	.04	4.78	1.02E+05	< .001	Time1:RegisterModal:GenderM:TLE	.51	.12	4.10	1.02E+05	< .001
Time3:TLE	.24	.03	7.89	1.02E+05	< .001	Time2:RegisterModal:GenderM:TLE	.24	.09	2.81	1.02E+05	.005
RegisterModal:TLE	.19	.03	6.64	1.02E+05	< .001	Time3:RegisterModal:GenderM:TLE	.56	.06	8.68	1.02E+05	< .001
GenderM:TLE	.59	.03	19.74	1.02E+05	< .001	Time1:RegisterModal:GenderM:Away	-.09	.13	-.73	1.02E+05	.464
Time1:Away	-.07	.06	-1.25	1.02E+05	.212	Time2:RegisterModal:GenderM:Away	.17	.09	1.88	1.02E+05	.060
Time2:Away	.28	.04	6.81	1.02E+05	< .001	Time3:RegisterModal:GenderM:Away	-.07	.07	-1.01	1.02E+05	.311
Time3:Away	.12	.03	4.01	1.02E+05	< .001	Time1:RegisterModal:TLE:Away	-.20	.15	-1.34	1.02E+05	.181
RegisterModal:Away	.03	.03	1.12	1.02E+05	.264	Time2:RegisterModal:TLE:Away	-.09	.11	-.83	1.02E+05	.404
GenderM:Away	-.07	.03	-2.18	1.02E+05	.029	Time3:RegisterModal:TLE:Away	-.16	.08	-2.06	1.02E+05	.040
TLE:Away	-.01	.04	-.15	1.02E+05	.881	Time1:GenderM:TLE:Away	.61	.19	3.15	1.02E+05	.002
Time1:RegisterModal:GenderM	.17	.06	3.02	1.02E+05	.003	Time2:GenderM:TLE:Away	-.16	.13	-1.24	1.02E+05	.215
Time2:RegisterModal:GenderM	.14	.04	3.50	1.02E+05	< .001	Time3:GenderM:TLE:Away	.82	.10	8.26	1.02E+05	< .001
Time3:RegisterModal:GenderM	.18	.03	6.33	1.02E+05	< .001	RegisterModal:GenderM:TLE:Away	.27	.09	2.89	1.02E+05	.004
Time1:RegisterModal:TLE	-.18	.08	-2.16	1.02E+05	.031	Time1:RegisterModal:GenderM:TLE:Away	.01	.27	.04	1.02E+05	.969
Time2:RegisterModal:TLE	-.18	.06	-3.10	1.02E+05	.002	Time2:RegisterModal:GenderM:TLE:Away	.25	.19	1.33	1.02E+05	.183
Time3:RegisterModal:TLE	-.22	.04	-5.25	1.02E+05	< .001	Time3:RegisterModal:GenderM:TLE:Away	-.14	.14	-1.02	1.02E+05	.310