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Research Article

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The Expanding Influence of Thai and its Effects on Cue Redistribution in Kuy

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1 Background

Much work on sound change has focused on language-internal motivations, with the role of language contact often viewed as secondary. However, as virtually all languages are in contact with others, it is just as important to understand in greater detail how contact effects change. The imposition of structural change from another language (Coetsem, 1988; Winford, 2005) requires some degree of bilingualism (Thomason & Kaufman, 1988: 66), the effects of which are particularly visible at the macro-level over long periods of time in areas where various languages coexist (Hinton, 1991; Ross, 2007). As most languages are minority languages existing among larger regional and national languages, insight into the mechanism by which imposition can lead to sound change may be gained by understanding social dynamics in such multilingual societies. To this end, the current study summarizes a production and perception study on Kuy [ISO 639-3: kdt] (Katuic, Austroasiatic), as spoken in Ban Khi Nak, Sisaket Province, in Northeast Thailand. In this study, I will focus on the modal vs. breathy voice quality contrast, although the reader may refer to Sriwises (1978); Yantreesingh (1980); Suwannaraj (1990); Sangmeen (1992); Sukgasame (2003); Phimjun (2004) and Markowski (2005) for full phonological descriptions on different Kuy[1] varieties. Being near the border of Cambodia and Laos, the Kuy generally live among Northern Khmer [ISO 639-3: kxm] (Austroasiatic)

1 Kuy is also alternatively spelled in other literature as Kui or Kuuy. Other groups refer to themselves as Kuay (also spelled Kuai or Kuoy) or Nyeu. The language should not be confused with Kui [ISO 639-3: kxu], a Dravidian language spoken in the Odisha state of India.

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Tab. 1: Experience living elsewhere, by generation

Age	Has not spent time away	Has spent time away
>40	28	23
<=40	5	44

This data is taken from the 100 participants[3] in the current study. "Has spent time away" is defined as having resided in a place that is not one of the Kuy villages in this study.

Tab. 2: Ban Khi Nak School timeline (`https://data.bopp-obec.info/emis/`, p.c. Sidawun Chaiyapha)

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

and Southern Lao[2] (Kra-Dai) speakers and regularly use these languages, alongside Thai [ISO 639-3: tha] (Kra-Dai), in everyday life.

The Kuy speaker population has been cited as approximately 250,000 (Smalley, 1994) or 400,000 (Premsrirat, 2006). Rapid modernization and centralization in Thailand has brought about more interregional travel (see Table 1) and longer schooling (see Table 2) in rural areas. Nowadays, schoolteachers tend to be recruited from other regions rather than locally, and many attend preschool and leave to finish high school and college. Subsequently, exposure to and usage of Thai has increased. The trend away from quadrilingualism among the Kuy can be seen in Table 3.[4] Whether stable multilingualism will persist in spite of these dynamics or give way to Thai monolingualism remains to be seen.

Given the expanding influence of Thai, which is tonal, it is perhaps unsurprising that a number of non-tonal languages in Thailand have been described as shifting toward tonal contrasts (Larish, 1997; Premsrirat, 2001; Sukgasame, 2003; Abramson et al., 2004; Abramson, 2004)[5]. Tsat, a Chamic (Austronesian) language whose speakers have been multilingual in tonal languages for centuries, offers circumstantial evidence for areal spread of tone (Thurgood, 1996, 2006, 2020a). Tonogenesis is theorized to involve reweighting of a secondary f0 cue in a contrast, such that it becomes transphonologized as the primary cue (Maran, 1973; Hyman, 1976). Such cue shifting has been demonstrated experimentally in modern lan-

Tab. 3: Language usage frequency compared to Kuy (100 speakers, data from current study)

	Thai			Khmer			Lao		
Age	Less	Same	More	Less	Same	More	Less	Same	More
>40	45	3	3	48	3	0	4	47	0
<=40	22	1	26	48	0	1	9	40	0

2 The term "Lao", as defined by linguists, refers to a swath of dialects ranging over Laos and Northeastern Thailand. Politically, however, the varieties in Northeastern Thailand, known as [pʰāːsǎː iːsǎːn] (Northeastern Thai), are considered dialects of Thai, separate from the varieties in Laos. As such, Northeastern Thai [ISO 639-3: tts] and Lao [ISO 639-3: lao] have many sociolinguistic differences. I will refer to the variety used by the Kuy as "Lao".

3 This number is not the sum of the participants in the production and perception studies because there was overlap in the participants.

4 The reader may refer to Phromthong (1996) and Tomioka (2019) for further work on Kuy language usage and language attitudes.

5 However, some of these claims have been challenged. For example, Maspong et al. (2020) does not find a significant pitch difference between vowels following initial geminates and those following initial singletons with her Pattani Malay speaker population, contra Abramson (2004).

guages (Kang, 2014; Kirby, 2014; Coetzee et al., 2018) and through comparative and historical evidence in Vietnamese and Chinese, Hmong-Mien, and Kra-Dai languages (Maspero, 1912; Li, 1948; Haudricourt, 1954; Li, 1966; Chang, 1972). Contemporary exploration of the role of multilingualism in tonogenesis has been more limited. One study by Brunelle (2009) suggests that bilingualism in Vietnamese may play an indirect role in augmenting f0 usage in Eastern Cham by enhancing preexisting differences. The current study contributes to this literature by exploring the interplay between sociolinguistic factors, language usage, and manifestation of the Kuy modal-breathy voice quality distinction. The underlying idea is that ability in a tonal language, in which f0 is the primary cue for a contrast, may enhance existing f0 differences in a contrast in a non-tonal language, catalyzing the phonologization of tone. Crosslinguistically, modal voice has, on average, higher f0 and F1 than breathy voice (Huffman, 1976; Ferlus, 1979; Kirby & Brunelle, 2017; Gehrmann & Kirby, 2019; Thurgood, 2020b). Effects of bilingualism on cue weights has been demonstrated in both perception and production (Llanos et al., 2013; Liu & Kager, 2015; Schertz et al., 2015; Stewart et al., 2018) and L2 knowledge has been shown to cause phonetic drift in L1 categories (Flege, 1987; Sancier & Fowler, 1997; Chang, 2010; Tremblay et al., 2017). Kuy, Khmer, and Northeastern Thai speakers in Northeastern Thailand produce Lao tones differently from each other (Pratankiet, 2001), with Kuy and Khmer speakers using a narrower pitch range (Sipipattanakun, 2014), suggesting effects from the lack of tone in Kuy and Khmer. The current study explores effects *from* tonal Thai and Lao on Kuy.

2 Experiment 1

This study was designed to assess the acoustic correlates of a voice quality contrast by Kuy speakers. If Kuy speakers are highly bilingual in Thai/Lao[6], they may exhibit weakened voice quality cues and/or strengthened f0 cues (potentially for auditory enhancement (Garrett & Johnson, 2013)), resulting from phonetic drift due to influence of Thai/Lao, which are both tonal and lack a voice quality contrast.

2.1 Methods

The experiment, lasting 30–45 minutes, was presented on a Google Nexus 10 tablet in a quiet room on temple grounds.[7] The participant's voice was recorded with a C544-L head-worn condenser microphone connected to an H4n Zoom recorder. To facilitate naturalness, participants were asked to construct their own carrier sentence by translating the example sentence in (1) from Thai into Kuy. (2) is one common translation. The target word retained prominence regardless of the sentence used.

(1)	cʰăn	pʰûːt	kʰam	wâː	náːm	hâj	kʰăw	faŋ
	1	say	word	COMP[8]	water	for	3	hear

'I say the word "water" for them to hear.'

(2)	haj	waw	pnaːj	paj	diaʔ	ɑːn	naw	cŋat
	1	say	word	COMP	water	for	3	hear

'I say the word "water" for them to hear.'

The participant was asked to keep their sentence in mind and to replace only the word 'water' with the presented stimulus. Figures (1) and (2) show a screen with the sample sentence and one with an experiment

6 Lao is also tonal and is a dominant community language in Northeast Thailand. It is also commonly used between transplants from Northeast Thailand in large cities.
7 This room was the quietest place that could be found in lieu of a soundproof laboratory space. The reader may refer to Whalen & 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.
8 Complementizer

stimulus, respectively. All the sentences were presented in Thai to avoid reading pronunciation and because Kuy does not have an established orthography. Pictures of the stimuli were provided below the sentence to aid in elicitation of the intended word.

Fig. 1: Example sentence in (1). Instructions above say "Please translate the following sentence into Kuy". The example Thai word /náːm/ 'water' is in red.

Fig. 2: Example sentence from task. The example word /náːm/ 'water' has been replaced with /k$^{\mathrm{h}}$àj/ 'egg' (in red). The expected Kuy word is /$^{\mathrm{n}}$trɛ̤ːl/.

The wordlist consisted of 58 stimuli (see Appendix A). Because voiceless unaspirated and aspirated stops are neutralized before breathy vowels[9], both types of stops were included. 31 of these stimuli were target words, consisting of 14 potential modal-breathy minimal pairs and 1 potential minimal triplet (modal unaspirated, modal aspirated, breathy). The remaining 27 words were distractors. Some speakers, particularly younger ones, lack prenasalization to varying extents; loss of prenasalization leads to the emergence of new minimal pairs (ex. /$^{(\text{ŋ})}$kæːŋ/ 'waist' vs. /kæ̤ːŋ/ 'side). Example minimal pairs from a speaker with a large breathiness distinction can be heard in (3) and (4) and one with a large f0 distinction in (5) and (6).

(3) /luː/ 'to howl' as produced by a 28-year old male speaker with clear breathiness difference
[howl_28m-1-laupreechathammarach.mp3 with example (3)]

(4) /lṳː/ 'thigh' as produced by a- 28-year old male speaker with clear breathiness difference
[thigh_28m-2-laupreechathammarach.mp3 with example (4)]

(5) /luː/ 'to howl' as produced by a 25-year old female speaker with clear f0 difference
[howl_25f-3-laupreechathammarach.mp3 with example (5)]

(6) /lṳː/ 'thigh' as produced by a 25-year old female speaker with clear f0 difference
[thigh_25f-4-laupreechathammarach.mp3 with example (6)]

After establishing the carrier sentence, I walked the participant through each stimulus once as a familiarization round, confirming that they were familiar with each word. The participant then completed 5 trial rounds alone (15–30 minutes), with stimuli shuffled each round and an optional break after round 3. There were 155 potential tokens per participant. Minimal pairs were included in the analysis only if the

9 A reviewer points out that neutralization tends to be towards aspirates in Katuic (Huffman, 1976; Diffloth, 1982; Gehrmann & Kirby, 2019). However, an analysis of voice onset time in the current production data (n = 4542) shows that although differences between all three groups are significant ($F_{2,4539} = 1557$, $p < .001$), neutralization of pre-breathy stops ($\mu = 26.75$, $\sigma = 15.86$) tends towards unaspirated pre-modal ones ($\mu = 16.89$, $\sigma = 8.68$) rather than aspirated pre-modal ones ($\mu = 66.33$, $\sigma = 31.13$). However, there are only 3 aspirated target words, so this result is tentative. A boxplot of VOT by stop type may be found in Appendix B.

Tab. 4: Number of Participants in Production Experiment, broken down by age and gender

	20s	30s	50s	60s
F	8	8	11	8
M	8	8	7	9

speaker produced at least 2 viable[10] tokens of each member of the pair. Following this task, the participant answered a series of demographic questions (translated into English in Appendix G) designed to determine language ability, domains and frequency of language usage, group identity, and residential history (Birdsong et al., 2012).

75 participants were recruited in total with the help of Kuy member Thongwilai Intanai, but 9 were excluded from the analysis for failing to complete the experiment, recording issues, producing fewer than 5 viable pairs, or extreme difficulty with the task, leaving data from 66 participants for analysis (see demographics in Table 4).

2.2 Results

A principal components analysis (PCA) was first implemented to reduce highly correlated social factors to a dimension comprising 36.7% of the social factor variance, to be termed as *Kuy Experience* (see Appendix C for details). *Time Away* (years spent living elsewhere, square rooted to reduce the right skew) and *Gender* were also included as factors. The dependent variables—f0, H1*, H1*-H2*, H1*-A1*, H1*-A2*, H1*-A3*, CPP, and F1—were calculated in Voicesauce (Shue et al., 2011) at 20 equidistant timepoints within target vowels. These measures are robust differentiators of voice quality (see Table 5), although their relevance differs by language (Holmberg et al., 1995; Kreiman et al., 2007; Keating et al., 2010; Kuang, 2011; Esposito, 2012; Khan, 2012) and both gender and age (Biever & Bless, 1989; Klatt & Klatt, 1990; Linville, 1992; Hanson, 1995, 1997; Hanson & Chuang, 1999; Linville, 2002; Bishop & Keating, 2012; Lee et al., 2015). As such, they were scaled by participant (F1 was also scaled by vowel height) using the `rescale` function in the `arm` package in R (Gelman & Su, 2020) for comparability.[11] Before normalization, f0 was converted into semitones to better approximate auditory distance (Nolan, 2003). Due to high potential covariance among spectral tilt measures, another PCA (see Appendix D for details) was implemented on CPP, H1*, H1*-A1*, H1*-A2*, and H1*-A3* (all spectral shape measures associated with voice quality). Of these, all but CPP and H1*-H2* were reduced to a dimension, *H1*(-*A_n**)*, comprising 45.34% of the voice quality variance. CPP and H1*-H2* each primarily loaded on dimensions 2 and 3, respectively, so these dimensions were not used. A mixed effects linear regression analysis was then carried out separately for f0, F1, H1*-H2*, H1*(-A_n*), and CPP with the `lme4` (Bates et al., 2015) package in R. The model looked at the interaction of 3 Timepoints (modeled with B-splines at 3 degrees of freedom), Voice Quality, Gender, Kuy Experience, and Time Away, with a random intercept for Word.[12]

Figures 3 through 7 plot the model predictions using the `effects` (Fox & Hong, 2009) package for each of the five measurements over Time by Voice Quality, Kuy Experience, Time Away, and Gender. As the results both with (n = 5125) and without (n = 4318) aspirated tokens were qualitatively similar, all tokens were ultimately included. The values for Kuy Experience and Time Away chosen for estimation are at the mean and ±1.5 standard deviations from the mean. If Kuy Experience or Time Away increases weighting of a given cue, the curves should be farther apart in a given row or column at one end of either continuum.

10 That is, at least 2 tokens of each pair had differ *only in voice quality (i.e. either both or neither are prenasalized).*
11 This involves centering the mean at 0 and dividing variables by two times their standard deviation for maximum interpretability. See Gelman (2008) for a discussion about this procedure.
12 A random intercept for Participant was not included as values are already normalized by participant.

Tab. 5: Voice quality measures: asterisk indicates corrections with formulas from Iseli et al. (2007)

	Explanation	**Expected pattern**
f0	fundamental frequency (Hz), correlate of pitch	modal > breathy
F1	first formant (Hz), correlate of vowel height	modal > breathy
H1*-H2*	amplitude of first harmonic - amplitude of second harmonic (dB), correlate of open quotient	breathy > modal
H1*(-An*)	amplitude of first harmonic (- amplitude of loudest harmonic of n^{th} formant), principal component comprising measures of spectral tilt	breathy > modal
CPP	cepstral peak prominence, measure of degree of periodicity	modal > breathy

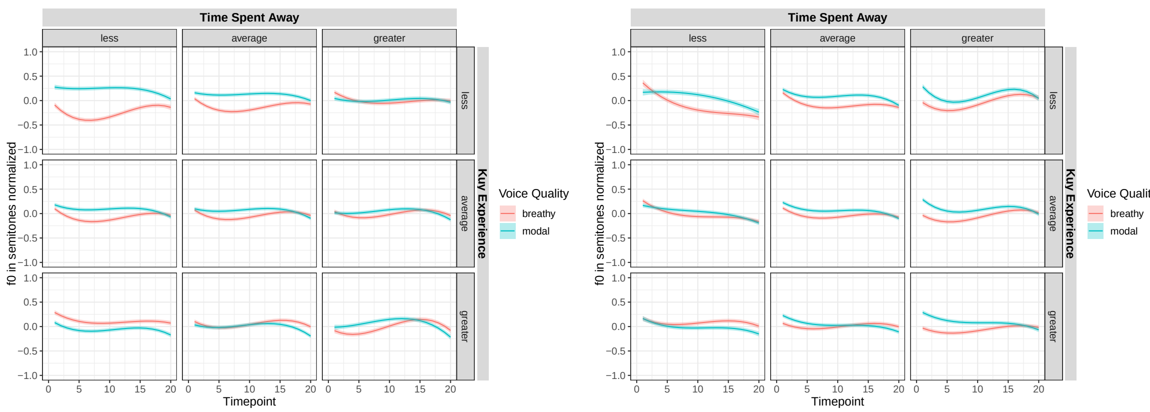

Fig. 3: Fitted f0 trajectories for female (left) and male (right) speakers

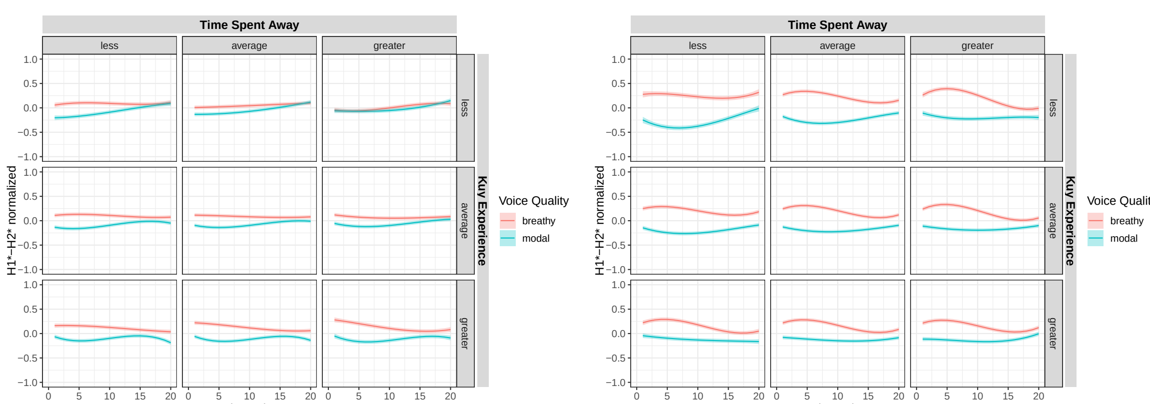

Fig. 4: Fitted H1*-H2* trajectories for female (left) and male (right) speakers

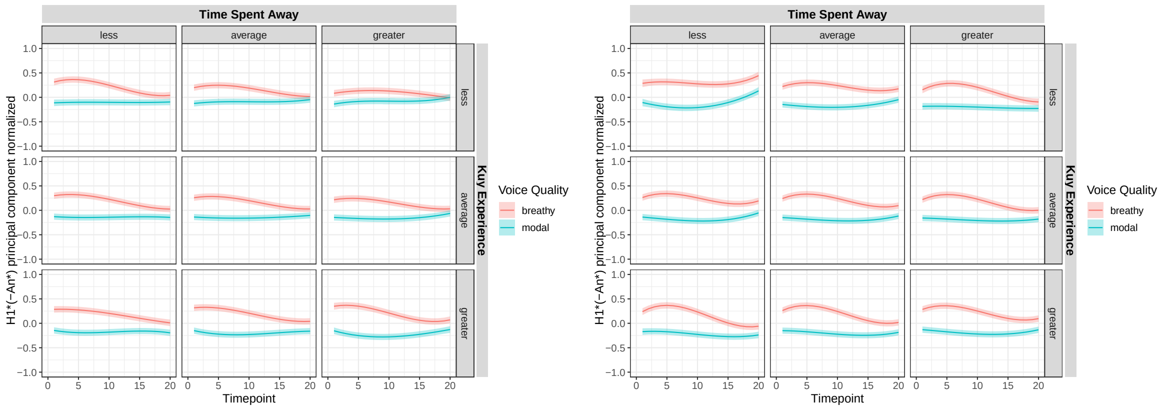

Fig. 5: Fitted H1*(-A_n*) trajectories for female (left) and male (right) speakers

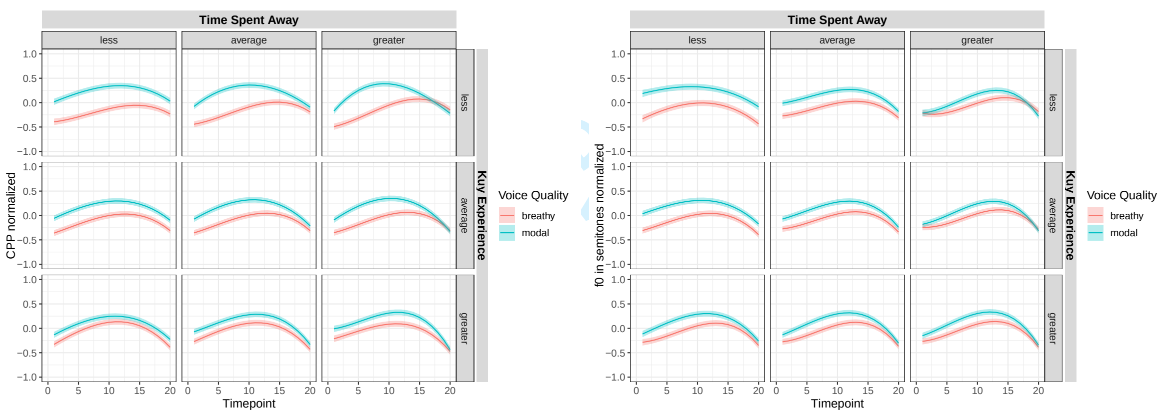

Fig. 6: Fitted CPP trajectories for female (left) and male (right) speakers

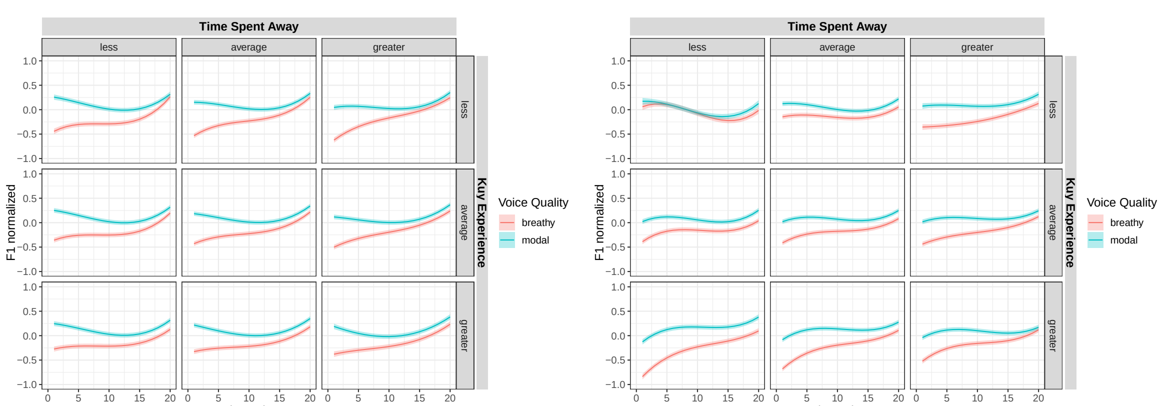

Fig. 7: Fitted F1 trajectories for female (left) and male (right) speakers

Due to normalization, the model results cannot be converted to units meaningful for comparison; instead, a summary of the raw data is provided in Table 6. Here, speakers are split into 2 levels of Kuy Experience and Time Away, cut off at the 50th percentile.[13] For each measure, the average difference between modal and breathy vowel means is calculated for timepoints 5 through 15 (the middle of the vowel) for each speaker. Each cell contains the mean of speaker means in a given group, with the range of means in parentheses.[14]

Greater Kuy Experience and less Time Away (bottom left of Figures 3 through 7) assumedly represents speakers least influenced by Thai/Lao and so will be considered the reference groups. For both genders, H1*-H2* (-3.29 dB; -4.47 dB)[15] and H1*(-A_n) (-3.76 dB; -4.79 dB)[16] are higher for breathy voice, while CPP (1.17 dB; 1.57 dB) and F1 (42.14 Hz; 35.28 Hz) are higher for modal voice, conforming to expected voice quality patterns (see Table 5). f0, however, is unexpectedly higher for breathy voice (-2.75 Hz; -4.83 Hz).

f0 differences are positive for all remaining groups: less Kuy Experience, less Time Away (15.44 Hz; 3.45 Hz); less Kuy Experience, greater Time Away (1.49 Hz; 5.18 Hz); greater Kuy Experience, greater Time Away (4.49 Hz; 1.09 Hz). CPP differences are also larger for less Kuy Experience groups (less Time Away: 2.52 dB; 2.74 dB; greater Time Away (2.40 dB; 1.93 dB) and greater Kuy Experience, greater Time Away females (1.58 dB). Notably, lower Kuy Experience speakers show significantly larger positive differences than the reference group for both measures and greater Time Away tempers the large f0 differences in lower Kuy Experience females.

Conversely, H1*-H2* (-3.29 dB; -4.47 dB) raw differences are largest for the reference groups and smallest for less Kuy Experience, less Time Away females (-1.64 dB). H1*(-An*) differences are largest for males in the reference group (-4.79 dB) and smallest for the less Kuy Experience, less Time Away groups (-3.59 dB; -3.50 dB).

Overall, the results support the hypothesis of increased f0 differences with lower Kuy Experience. However, contrary to the hypothesis, other voice quality cues are not uniformly weakened and Time Away shows inconsistent effects.

13 If we only look at speakers with the extreme value combinations at the corners of the model, the number of speakers in some bins is too few for meaningful summary statistics.

14 It must be noted that these raw values are *attenuated* as compared to model estimates at continua endpoints as each bin necessarily contains speakers with intermediate Kuy Experience and Time Away values.

15 These parenthetical measures may be read as (female mean; male mean).

16 For H1*(-A_n), the value is the average of means of all the H1*(-A_n) measures.

Tab. 6: Raw differences (modal - breathy) between cues by group: overall means (range of speaker means)

	Female			
Kuy Experience:	Greater	Less	Greater	Less
Time Away:	Less	Less	Greater	Greater
n	11	8	6	9
f0 (Hz)	-2.75 (-19.71, 12.43)	15.44 (7.90, 30.23)	4.49 (-6.81, 24.23)	1.49 (-39.76, 21.74)
H1*-H2* (dB)	-3.29 (-9.30, 0.62)	-1.64 (-2.27, -0.48)	-2.69 (-3.95, -1.64)	-2.17 (-12.18, 4.03)
H1* (dB)	-3.91 (-6.56, -2.03)	-3.49 (-4.37, -2.65)	-4.02 (-6.09, -1.37)	-3.88 (-8.09, -1.94)
H1*-A1* (dB)	-3.48 (-9.63, 0.77)	-2.41 (-5.88, -0.67)	-3.40 (-6.84, -0.60)	-2.74 (-6.77, 0.25)
H1*-A2* (dB)	-3.62 (-6.69, -1.11)	-3.88 (-5.63, -1.54)	-4.99 (-7.83, -3.12)	-4.52 (-8.83, -0.88)
H1*-A3* (dB)	-4.03 (-7.72, -0.46)	-4.59 (-5.77, -2.90)	-5.09 (-7.28, -1.30)	-3.75 (-7.94, 0.57)
H1*(-A_n)[17]	-3.76 (-9.63, 0.77)	-3.59 (-5.88, -0.67)	-4.38 (-7.83, -0.60)	-3.72 (-8.83, 0.57)
CPP (dB)	1.17 (-0.52, 2.92)	2.52 (1.58, 4.12)	1.58 (0.69, 3.24)	2.40 (1.18, 4.34)
F1 (Hz)	42.14 (9.69, 94.84)	48.48 (28.60, 79.28)	32.66 (-0.76, 65.72)	26.20 (-28.43, 58.38)
	Male			
Kuy Experience:	Greater	Less	Greater	Less
Time Away:	Less	Less	Greater	Greater
n	9	8	7	8
f0 (Hz)	-4.83 (-41.91, 14.44)	3.45 (-4.16, 14.87)	1.09 (-12.15, 9.50)	5.18 (-2.48, 13.34)
H1*-H2* (dB)	-4.47 (-10.03, 0.50)	-3.75 (-8.86, -1.22)	-3.42 (-6.59, -1.32)	-3.73 (-6.52, -1.51)
H1* (dB)	-4.42 (-7.28, -2.56)	-3.64 (-4.82, -2.98)	-4.12 (-5.80, -2.89)	-3.65 (-5.47, -2.30)
H1*-A1* (dB)	-4.32 (-7.98, -2.70)	-2.85 (-5.58, 0.28)	-3.86 (-6.51, -1.42)	-4.14 (-6.44, -2.11)
H1*-A2* (dB)	-5.48 (-10.14, -2.51)	-4.13 (-6.44, -1.50)	-4.40 (-8.32, -0.11)	-5.19 (-10.10, -3.06)
H1*-A3* (dB)	-4.92 (-7.64, -3.07)	-3.36 (-4.69, -1.36)	-3.91 (-7.19, -0.03)	-4.07 (-9.06, 0.09)
H1*(-A_n)	-4.79 (-10.14, -2.51)	-3.50 (-6.44, 0.28)	-4.07 (-8.32, -0.11)	-4.26 (-10.10, 0.09)
CPP (dB)	1.57 (0.78, 3.04)	2.74 (-0.43, 3.07)	1.22 (0.14, 2.11)	1.93 (0.87, 3.11)
F1 (Hz)	35.28 (5.80, 83.50)	35.98 (17.73, 59.39)	36.13 (-60.20, 86.29)	27.25 (-13.29, 64.72)

3 Experiment 2

The perception study was a two-alternative forced choice task designed to evaluate the relative cue weighting of acoustic cues in the voice quality contrast. Stimuli were synthesized on the basis of data from the production study.

3.1 Methods

The two most consistently produced minimal pairs in the production study (/tiː/ 'old' vs. /ti̤ː/ 'tall' and /taʔ/ 'grab' vs. /ta̤ʔ/ 'to place under') were chosen as targets of synthesis. For each pair, a continuum ranging from one member to the other was created using the KlaatGrid synthesizer (Weenink, 2009) through a Praat script adapted from Brunelle & Kirby (2020). The continuum varied on fundamental frequency (f0) and open quotient (OQ), a voice quality cue related to acoustic measures (especially H1*-H2*) in the production experiment, for the first half of the vowel. The beginning f0 value ranged from 110 Hz to 140 Hz while OQ ranged from 30% and 70%, both at 5 evenly spaced intervals. The middle f0 (125 Hz) and H1*-H2* (50% OQ) trajectories lay between the average trajectories of /a/ and /a̤/ for *taʔ* and /iː/ and

17 Means are averaged from the H1*, H1*-A1*, H1*-A2*, and H1*-A3* means, whereas the range is determined by the lowest and highest range values for these measures.

Tab. 7: Demographics and Conditions

Variable	Conditions
Gender	F M
Decade	20s 30s 50s 60s
First Syllable	tiː taʔ
Image Orientation	1st block: modal left; 2nd block: modal left 1st block: modal left; 2nd block: breathy left 1st block: breathy left; 2nd block: modal left 1st block: breathy left; 2nd block: breathy left

/i̤ː/ for *tiː* from a 24- and 61-year old male speaker with a clear f0 and H1*-H2* distinction, respectively, yielding 25 stimuli for each continuum. The F1 trajectory was synthesized to be intermediate between the two voices as F1 effects were not the focus of the study. Stimuli were piloted and adjusted for naturalness (see Appendix E for parameters and supplemental materials for audio).

The experiment was presented in OpenSesame (Mathôt et al., 2012) on a Microsoft Surface Go tablet on temple grounds. In each block, the participant was presented two images, each representing a member of the minimal pair (see Figures 8 and 9). The participant used a stylus to swipe the picture representing the word they heard through AKG K240 Studio Headphones. The stimuli were randomized and presented with 500ms interstimuli intervals. After I sat with the participant through a practice block for each syllable, the participant proceeded alone through 16 trial blocks (15–30 minutes), alternating between the two syllables, yielding a total of 400 tokens.

Fig. 8: *tiː* block: /tiː/ 'old' vs. /ti̤ː/ 'tall'

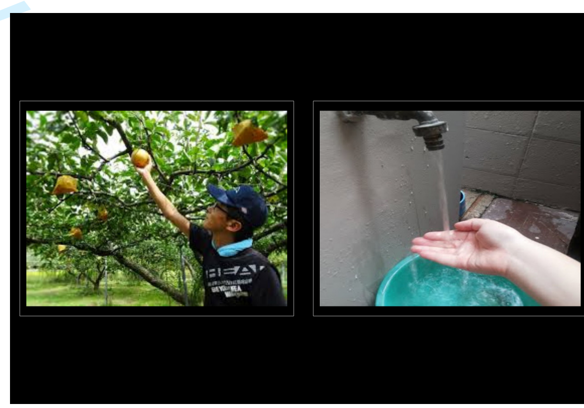

Fig. 9: *taʔ* block: /taʔ/ 'to grab' vs. /ta̤ʔ/ 'to place under'

To account for left-right bias, the images swapped position in each consecutive block of a given syllable. Ordering effects were accounted for by assigning each participant within each decade-gender group a unique first-syllable and first-orientation condition. The demographics and conditions are laid out in Table 7.

This study sought a stratified sample of 64 participants, evenly distributed by gender and decade. 74 participants were recruited in total, again with help from Thongwilai Intanai. 10 were excluded from the 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. The same questionnaire from Experiment 1 was administered after, alongside an interview on identity, language attitudes, and experience away from home.

3.2 Results

A PCA (see Appendix F for details) reduced the social factors to *Kuy Experience* (39.50% of the variance, with contributions primarily from the same factors as Experiment 1) and *Thai Integration* (14.67% of the variance, positively correlated with time away and negatively with Kuy Identity). A mixed effects logistic regression analysis (n = 25,328) examined the effect of the interaction of OQ, f0, Gender, Kuy Experience, and Thai Integration, fitted with random intercepts for Participant and Syllable, on the voice quality chosen.[18]

The model estimates for percent likelihood of choosing "breathy" at 100 evenly spaced OQ values by each interaction term are visualized in Figure 10. As in the production study, the values for Kuy Experience and Thai Integration used for estimation are at the mean and ± 1.5 standard deviations away. If f0 weights are strengthened, the response curves should be further apart. If OQ cue weights are weakened, responses at the endpoints should be less extreme, as even extreme OQ values may yield equivocal responses.

Higher OQ and lower f0 values expectedly yield more breathy responses. As hypothesized, less Kuy Experience spreads out response curves (compare top to bottom row), even at the endpoints, showing a tradeoff—weakened OQ cues, stronger f0 cues. Greater Thai Integration, however, does not spread the curves, but flattens them (compare right column to left), suggesting that OQ cues are weakened without tradeoff. The less Kuy Experience, less Thai Integration combination shows a large influence from f0 in low-OQ stimuli. As Thai and Lao lack a voice quality distinction and so listeners of these languages hear tonal distinctions only in modal voice, it is reasonable that heavier weighting of f0 from greater usage of Thai/Lao would be transferred primarily to perception of modal tokens.

While the response curve shapes are generally the same for male and female listeners, females show flatter curves overall, suggesting that they weigh OQ less strongly than males. Less Kuy Experience also does not increase f0 weights for female listeners as much as for males. Among female speakers with less Kuy experience, lower Thai Integration (top left) leads to bias towards breathy responses while greater Thai Integration (top right) leads to bias towards modal responses. The modal bias in high Thai Integration speakers may reflect greater difficulty in perceiving breathy voice.

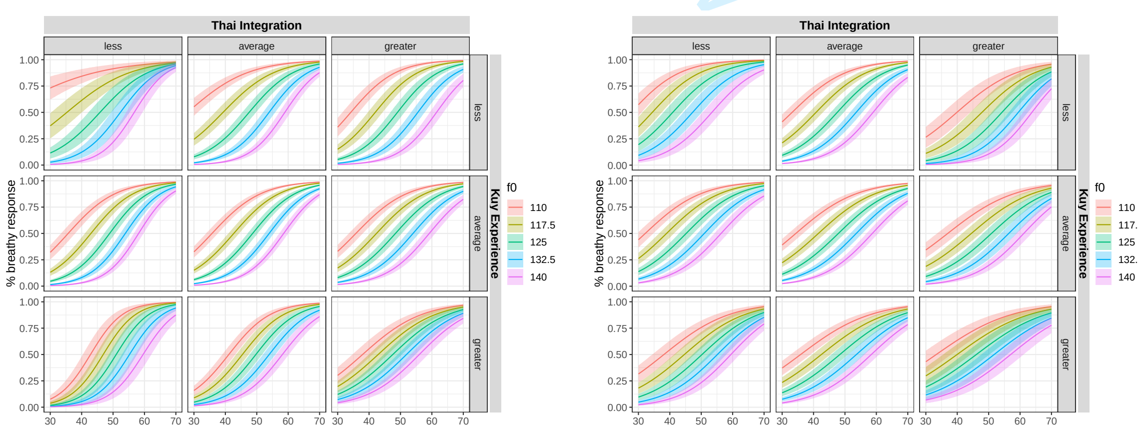

Fig. 10: Fitted response curves split by f0 for male (left) and female (right) speakers

18 One speaker's responses for *tiː* were excluded from the analysis as the response pattern was random.

4 Discussion

The production and perception studies together provide promising evidence for the role of tonal language usage in increasing f0 cue weights in a non-tonal language. The relationship between Kuy Experience (inversely correlated with Thai/Lao usage) and Time Away is initially confusing, appearing to strengthen f0 if Kuy Experience is high but weaken it if it is low (as well as some other cues too, especially for women). However, the individual f0 trajectories in the left graphs in Figures 11 and 12 demonstrate that enhanced f0 cues in high Kuy Experience speakers are driven by a small number of speakers (one female speaker away for 23 years, and two male speakers away for 31 and 47 years), skewing the model. Looking at the right graphs, many more low Kuy Experience speakers have clear f0 differences, especially those not away as long. The enhancement of f0 cues with less Kuy Experience is mirrored in the perception results, as is the attenuation of this effect for females also highly integrated into Thai society (correlated to Time Away). While female speakers have the largest f0 differences in production, it is actually male speakers who weigh f0 more heavily in perception.

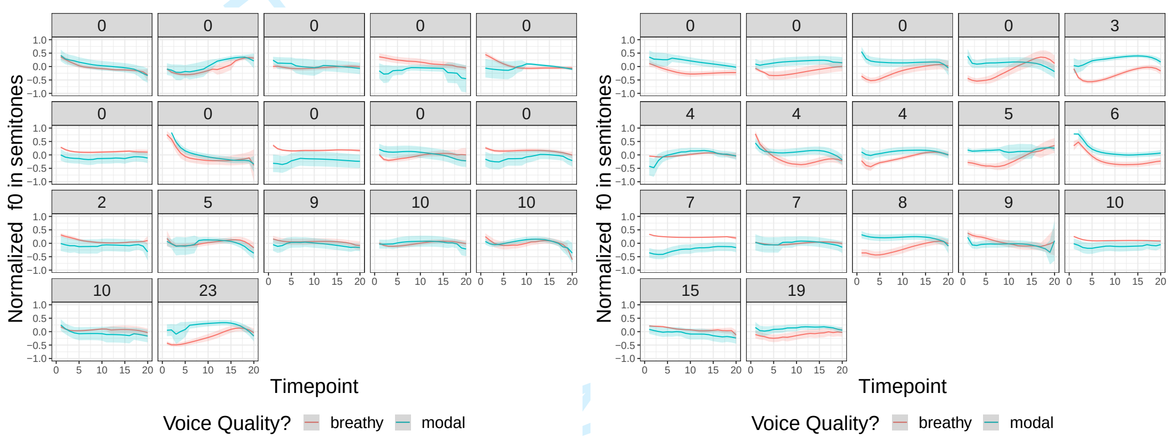

Fig. 11: f0 trajectories for high (left) and low (right) Kuy Experience female speakers, sorted by Years Away

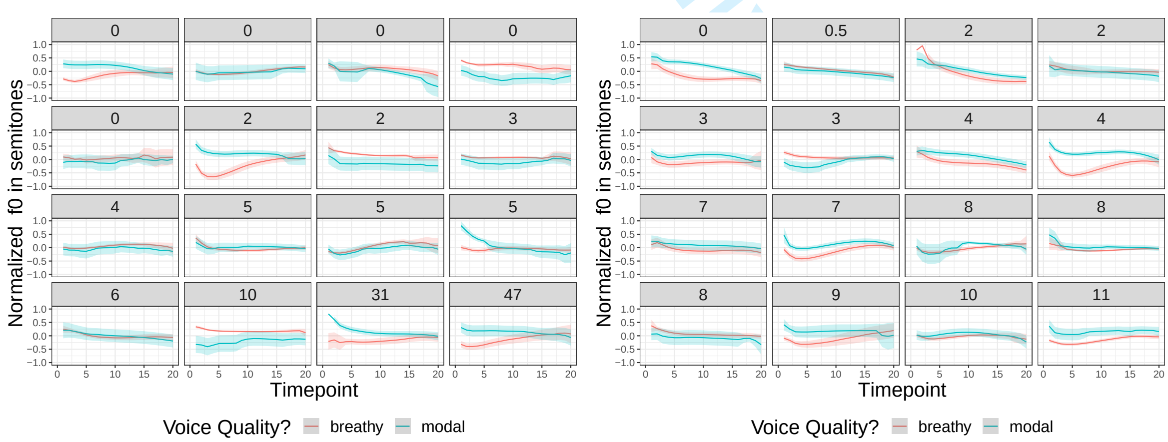

Fig. 12: f0 trajectories for high (left) and low (right) Kuy Experience male speakers, sorted by Years Away

The effects of social factors on other cues are conflicting between the two experiments. In perception, there is tradeoff for f0 with greater Thai/Lao usage, but weakening of the cues without tradeoff with greater integration into Thai society. In production, effects are murkier, although greater Thai/Lao usage notably strengthens CPP. The flattened response curves from greater Thai Integration, especially for males, are not reflected in weakened cues from greater Time Away in production.

Conflicting results in production and perception are unsurprising. First, the overlap of participants is only partial. Second, while Time Away in the production experiment and Thai Integration in the perception experiment are both meant to get at the same idea, they are not fully comparable, as the second measure also includes Kuy identity. Third, the acoustic space is delimited by set parameters in the perception experiment but by the speaker in the production experiment. Voice quality measures related to harmonics are not directly manipulable for perceptual stimuli but rather involve tweaking the OQ factor to approximate voice quality measures. Because OQ manipulation primarily affected H1*-H2*, we might expect the voice quality results in perception to best match the H1*-H2* results in production. However, the weakening of H1*-H2* with greater Thai Integration does not correspond to the production results. The lack of F1 manipulation in the perception study may also play a role in conflicting results, given notable F1 differences in production for many speakers.[19] Such obstacles in comparison between production and perception tasks are a common difficulty (Schertz & Clare, 2020). Regardless, we can still comment on similarities between the results.

The most striking result is that in both experiments, the heaviest weighting of f0 occurs when Kuy Experience and Thai Integration are both low. These speakers use a great deal of Thai/Lao but still likely use Kuy very often, given its regular usage in the village. Many of them also have a strong sense of Kuy identity. The fact that the effect is especially visible in perception of the most modal stimuli further implicates the influence of Thai/Lao on perception of the Kuy contrast, as input of Thai/Lao tonal contrasts is all in modal voice. Many of these same speakers also show a greater use of CPP cues, suggesting that the Kuy voice quality contrast may be shifting to be primarily loaded on f0 and CPP. Another notable result is the general weakening of some of the voice quality cues in both perception and production in those who are both Thai/Lao-dominant and have also spent more time away from the village. As these speakers not only prefer to use Thai/Lao, but also have spent long swaths of time neither producing nor perceiving Kuy, the weakening of the contrast may reflect language attrition from a sudden shift to Thai/Lao, which lack a voice quality contrast, thus potentially causing phonetic drift.

Three conclusions are suggested by the results: (1) The propagators of change are highly proficient users of Thai/Lao that stay in the village and/or exhibit a strong Kuy identity. (2) The general weakening of the contrast may be triggered by a combination of lower Kuy proficiency/usage and high integration into Thai society. (3) The voice quality contrast appears to be shifting from reliance on non-f0 cues to reliance on f0 and CPP. Why CPP is becoming a prominent cue in the contrast remains a topic for future work. A deeper look into individual differences will provide a clearer picture of the mechanisms at work in the perception-production link and shed light on the messiness of the variable of integration into Thai society.

Of potential relevance to these cue shifts are the ongoing changes of prenasalization loss and coda /l/ and /r/ merger, both of which some speakers in this study exhibit and which simplify the Kuy onsets and codas. The simplified syllable structure increases the number of minimal pairs and functional load on the suprasegmental voice quality, leading to a pressure to enhance voice quality cues at the risk of merger.[20] Thai/Lao, which both lack prenasalization and permit fewer codas than Kuy, may be involved in these changes *and also* pressure enhancement of voice quality cues in the direction of increased f0 cue weighting. Thus, internal changes conducive to contrast enhancement and the external role of multilingualism with tonal languages may conspire to pave the way for potential tonogenesis.

19 Intermediate F1 values were chosen to prevent an overly lengthy experiment, though F1 manipulation is necessary in future study for a fuller picture of cue usage in Kuy.

20 A related process that simplifies syllable structure is monosyllabization, which is considered to be a catalyst for tonogenesis (Matisoff, 2001; Michaud, 2012; Kirby & Brunelle, 2017).

While tonogenesis has not yet happened, as breathiness cues (especially CPP) are still utilized, the results do suggest that salient changes are occurring. Such changes, albeit incremental, lay the groundwork for potential structural change. The results may provide support for multilingualism as a potential catalyst for the spread of tone through maintenance of an ancestral non-tonal language in a community with enough speakers who are highly bilingual in a tonal language. The drivers of change are proficient multilinguals who stay at home and/or have a strong sense of Kuy identity. Thus, the change appears to be more likely to take place in the event that the language remains robust despite increasing Thai usage. If the language goes down the road of attrition, cues may diminish without compensation. This situation encapsulates the plight of endangered languages: with the ever-growing dominance of larger national languages, small language communities experience increasing pressures to shift to dominant languages. While harmony of Thai and Kuy in the community could lead to transformation of the voice quality contrast, language loss is always a risk with the ever-growing dominance of the national language.

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This research was approved by the Committee for Protection of Human Subjects at the University of California, Berkeley, including signatures of informed consent for collection of audio data. The research presents no more than minimal risk to and does not adversely affect the rights and welfare of subjects.

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Appendix A: Stimuli in Experiment 1

Tab. 8: Production Stimuli

Targets	Gloss	Distractors	Gloss
^{n}c^{h}uːn	‘to hide’	buʔ	‘to sow’
c̤uːn	‘to send’	^{n}cɛː	‘louse’
^{ŋ}kɛːŋ	‘waist’	^{n}c^{h}ɑːʔ	‘hay’
kɛ̤ːŋ	‘side’	^{n}c^{h}ɔʔ	‘smelly’
kuː	‘to exist’	cntrʌ̤ŋ	‘diligent’
kṳː	‘every’	cɤ̤ːl	‘tiger’
lɑp	‘to return’	da̤h	‘to bite (and break)’
lɑ̤p (lɑ̤p)	‘dusk’	daʔ	‘to place’
luː	‘to howl’	k^{h}al	‘scooping bowl’
lṳː	‘thigh’	kʌ̤l	‘tree’
p^{h}oːm	‘fragrant’	k^{h}oːk^{h}oː	‘toasted rice’
^{m}po̤ːm	‘just (now)’	ko̤ː	‘cow’
piːl	‘flower’	ktɤː	‘season’
pi̤ːl	‘to wind’	^{ŋ}kʌŋ	‘eggplant’
poːt	‘swelling’	lmpaːʔ	‘shoulder’
po̤ːt	‘too much’	^{m}pe̤ːʔ	‘mother’
puːʔ	‘sun’	p^{h}lɯːm	‘lightning’
pṳːʔ	‘beard’	rmpa̤t	‘stick’
taʔ	‘to grab (from above)’	sɛh	‘horse’
ta̤ʔ	‘to place under’	sʌːŋ	‘five’
tah	‘to divorce’	sŋkiːl	‘sensitive’
ta̤h	‘to slap’	tmpoːm	‘that which is wrapped’
t^{h}eː	‘jar’	^{n}tɔːl	‘star’
(^{n})teː	‘to tell’	^{n}trɑːŋ	‘red ant’
te̤ː	‘no’	t^{h}rɛː	‘rice paddy’
tiː	‘old’	^{n}trɛ̤ːl	‘egg’
ti̤ː	‘tall’	^{n}tri̤ːm	‘shovel’
toːŋ	‘coconut’		
to̤ːŋ	‘male (animal)’		
t(ia̤ŋ)pat	‘west’		
tpa̤t	‘six’		

Appendix B: Stop Voice Onset Time Differences

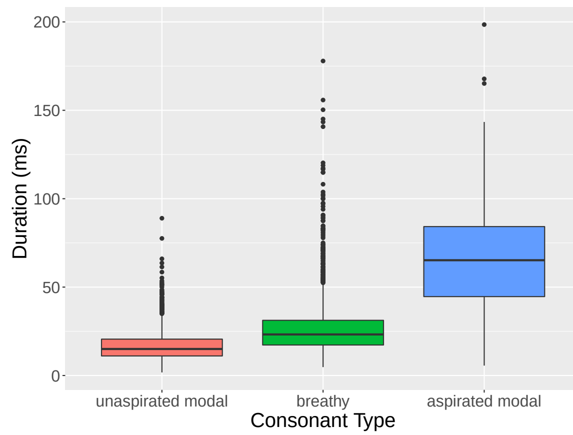

Fig. 13: Boxplot of VOT distributions by consonant type

Figure 13 shows the distributions of the VOT values for unaspirated stops before modal vowels (n = 1937, $\mu = 16.89$, $\sigma = 8.68$), aspirated stops before modal vowels (n = 342, $\mu = 66.33$, $\sigma = 31.13$), and stops before breathy vowels (n = 2263, $\mu = 26.75$, $\sigma = 15.86$). Differences between all three groups are significant ($F_{2,4539} = 1557$, $p < .001$). Aspiration is neutralized before breathy vowels, with this analysis showing that the VOT is closer to pre-modal unaspirated stops (+9.86 ms) than to pre-modal aspirated stops (-39.58 ms). However, the results should be taken with caution as there are only 3 aspirated target words.

Appendix C: PCA on Social Variables (Experiment 1)

Tab. 9: Social Factor Correlation Matrix for Production Experiment

	Age	√(Years Away)	Understand	Speak	Overall Freq	Family Freq	Friend Freq	ID
Age	1.00							
√(Years Away)	-0.13	1.00						
Understand	0.51	0.07	1.00					
Speak	0.41	0.07	0.61	1.00				
Overall Freq	0.33	-0.07	0.29	0.53	1.00			
Family Freq	-0.12	-0.07	-0.11	0.16	0.30	1.00		
Friend Freq	0.55	-0.25	0.39	0.44	0.65	0.09	1.00	
ID	0.05	-0.09	-0.04	0.17	0.22	0.08	0.09	1.00

The factors fed into the social variable PCA are in the correlation matrix in Table 9. These factors are explained below. The questions from which they are derived may be seen in Appendix G. The first component of the PCA accounts for 36.7% of the variance, comprising primarily of Friend Freq (22.37%), Speak (21.08%), Overall Freq (19.86%), Age (17.39%), and Understand (16.37%). A scree plot of the percentage of variance accounted for by each dimension is in Figure 14 and contributions of the social factors to the first dimension (Kuy Experience) are in Figure 15. Lower dimensions were unused because of difficulty of interpretability.

- **Age:** Participant's age in years.
- **√(Years Away):** Years spent living in another (non-Kuy speaking) area. Square rooted to reduce heavy right skew.
- **Understand:** Ability to understand Kuy (coded from 0-5) minus ability to understand Thai or Lao (coded from 0-5; the higher ranking between the two languages is chosen).
- **Speak:** Ability to speak Kuy (coded from 0-5) minus ability to speak Thai or Lao (coded from 0-5; the higher ranking between the two languages is chosen).
- **Overall Freq:** Overall frequency of using Kuy (coded from 0-100) minus overall frequency of using Thai or Lao (coded from 0-100; the higher number between the two languages is chosen).
- **Family Freq:** Frequency of using Kuy with family (coded from 0-100) minus frequency of using Thai or Lao with family (coded from 0-100; the higher number between the two languages is chosen).
- **Friend Freq:** Frequency of using Kuy with friends (coded from 0-100) minus frequency of using Thai or Lao with friends (coded from 0-100; the higher number between the two languages is chosen).
- **ID:** Self-rating of Kuy identity (coded from 0-3) minus self-rating of Thai or Lao identity (coded from 0-3; the higher number between the two languages is chosen).

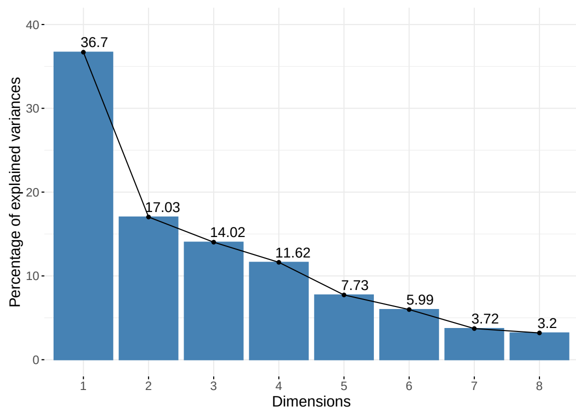

Fig. 14: Scree plot for PCA on Social Variables

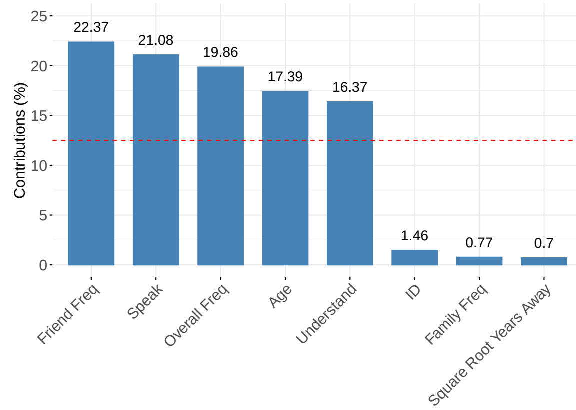

Fig. 15: Contributions of Social Variables to Dimension 1 (Kuy Experience)

Appendix D: PCA on Voice Quality Variables (Experiment 1)

The factors fed into the voice quality PCA are in the correlation matrix in Table 10. These factors are explained below (an asterisk indicates correction via formulas by Iseli et al. (2007)). The first component of the PCA accounts for 45.34% of the variance, comprising primarily of H1*-A2* (25.09%), H1*-A1* (24.03%), H1*-A3* (23.30%), and H1* (21.07%). A scree plot of the percentage of variance accounted for by each dimension is in Figure 16 and contributions of the voice quality factors to the first dimension (H1*(-An*)) are in Figure 17. Lower dimensions were unused because of difficulty of interpretability or being primarily loaded on by one factor.

- **H1*-A1*:** Amplitude of the first harmonic minus amplitude of the loudest harmonic of the first formant, corrected; measure of spectral tilt
- **H1*-A2*:** Amplitude of the first harmonic minus amplitude of the loudest harmonic of the second formant, corrected; measure of spectral tilt
- **H1*-A3*:** Amplitude of the first harmonic minus amplitude of the loudest harmonic of the third formant, corrected; measure of spectral tilt
- **H1*:** Amplitude of the first harmonic, corrected
- **H1*-H2*:** Amplitude of the first harmonic minus amplitude of the second harmonic, corrected; correlate of open quotient
- **CPP:** Cepstral peak prominence; measure of degree of periodicity and correlated with harmonics-to-noise ratio

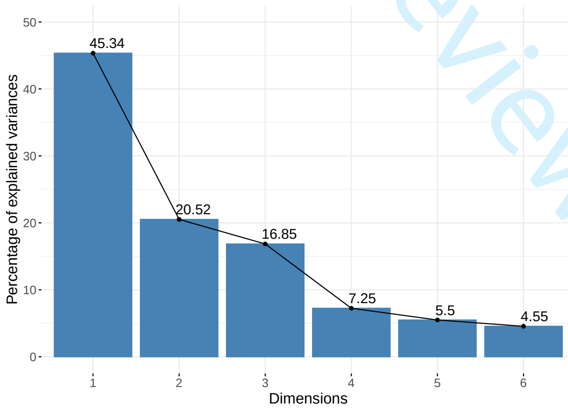

Fig. 16: Scree plot for PCA on Voice Quality Variables

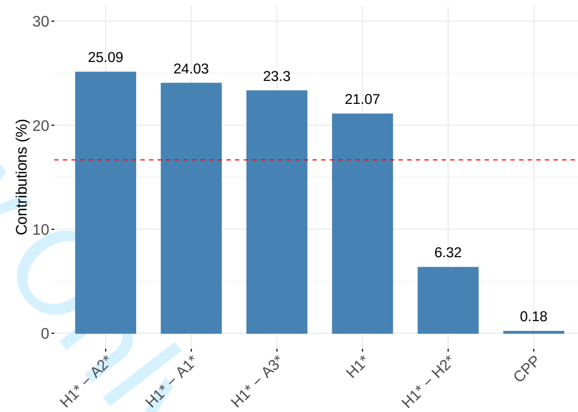

Fig. 17: Contributions of Voice Quality Variables to Dimension 1 (H1*(-An*))

Tab. 10: Voice Quality Factor Correlation Matrix for Production Experiment

	H1* - A1*	H1* - A2*	H1* - A3*	H1*	H1* - H2*	CPP
H1* - A1*	1.00					
H1* - A2*	0.69	1.00				
H1* - A3*	0.58	0.56	1.00			
H1*	0.40	0.44	0.51	1.00		
H1* - H2*	0.12	0.23	0.11	0.47	1.00	
CPP	0.06	-0.13	0.15	0.19	-0.20	1.00

Appendix E: Stimuli in Experiment 2 1

Tab. 11: Perception Stimuli Klatt Parameters

	taʔ	tiː
p1 (Power 1)	1	1
p2 (Power 2)	10	3
VOT	10 ms	15 ms
Duration	200 ms	400 ms
F1 begins at	800 Hz	350 Hz
F1 ends at	900 Hz	425 Hz
Midpoint f0	125 Hz	135 Hz

In Table 11 are some relevant settings for the current stimuli. Readers may request the Praat script from 2
the author. Stimuli were modified following multiple rounds of piloting until they were considered natural 3
by listeners and until there was not a heavy bias towards modal or breathy responses. A VOT of 20 ms 4
was originally used for both syllables as an intermediate value between the VOT of unaspirated stops 5
preceding modal vowels and stops preceding breathy vowels, but this value led to a heavy bias towards 6
breathy responses. As such, the VOT was reduced following the guidance of pilot participants. 7

Appendix F: PCA on Social Variables (Experiment 2)

Tab. 12: Social Factor Correlation Matrix for Perception Experiment

	Age	√(Years Away)	Understand	Speak	Overall Freq	Family Freq	Friend Freq	ID
Age	1.00							
√(Years Away)	-0.26	1.00						
Understand	0.54	-0.16	1.00					
Speak	0.37	-0.04	0.44	1.00				
Overall Freq	0.41	-0.11	0.33	0.40	1.00			
Family Freq	0.13	-0.06	0.17	0.36	0.41	1.00		
Friend Freq	0.61	-0.13	0.43	0.41	0.66	0.25	1.00	
ID	0.13	-0.27	0.14	0.09	0.29	0.24	0.13	1.00

The factors fed into the social variable PCA are in the correlation matrix in Table 12. These factors are explained below Table 9. The questions from which they are derived may be seen in Appendix G. The PCA revealed the first component accounting for 39.5% of the variance, comprising primarily of Friend Freq (20.31%), Overall Freq (18.80%), Age (17.48%), Understand (14.63%), and Speak (13.97%) and the second component accounting for 14.67% of the variance, comprising primarily of ID (46.33%) and Square Root Years Away (37.88%). A scree plot of the percentage of variance accounted for by each dimension is in Figure 18. Contributions of the social factors to the first (Kuy Experience) and second (Thai Integration) dimensions are in Figures 20 and 21 and the coordinates of each factor on the first two dimensions may be found in Figure 19, showing their orthogonality. Lower dimensions were unused because of difficulty of interpretability.

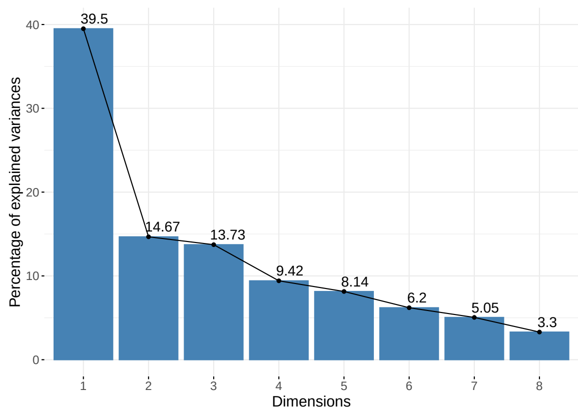

Fig. 18: Scree plot for PCA on Social Variables

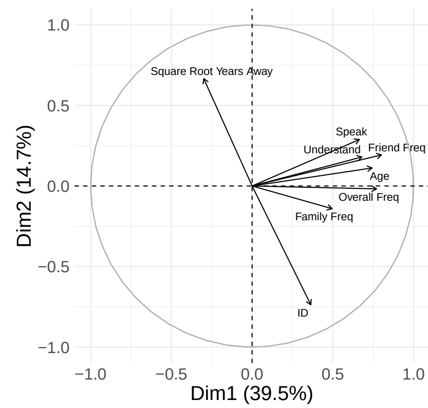

Fig. 19: Social factor contributions to Dimensions 1 and 2

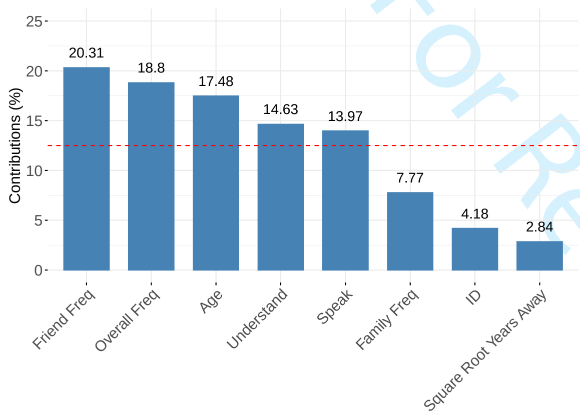

Fig. 20: Contributions of Social Variables to Dimension 1 (Kuy Experience)

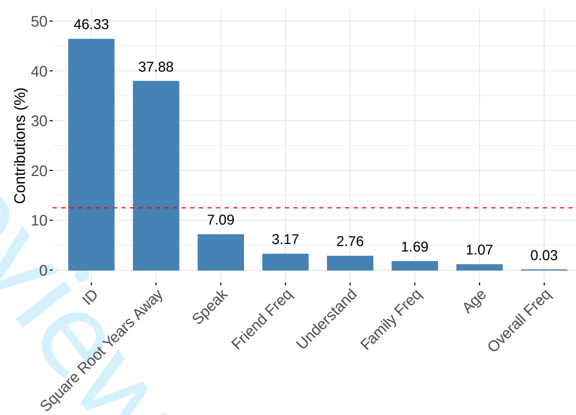

Fig. 21: Contributions of Social Variables to Dimension 2 (Thai Integration)

Appendix G: Demographic Questionnaire (translated to 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?

....

1

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? ___________________

1

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 ....

1

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 ....