

## On the Alternation of Taiwanese Hokkien Coda Stops

### 1 Introduction

Apart from the complicated tone sandhi systems, little or no studies have paid close attention to the phenomena that happen across syllable boundaries in the history of research on the phonology of Sinitic languages. Presumably, this is due to the fact that its biggest dialect, Mandarin Chinese (Chinese: 官話 *Guānhuà*), has lost all the coda consonants except /n/ and /ŋ/ before the 6<sup>th</sup> century, thus, only limited phenomena happen at the syllable boundaries. Meanwhile, varieties like Southern Min (Chinese: 閩南語 *Minnányǔ*; POJ: *Bân-lâm-oē*) retain all the syllable-final consonants corresponding to those of Middle Chinese, i.e. /m, n, ŋ, p, t, k/, with additional development of /ʔ/. These coda consonants are also retained by Sino-Korean vocabularies, with a historical change from /\*t/ to /l/ (e.g. MC 骨 \*kuət, Kor. 골 *kol*), and these consonants are subjected to various rules including progressive and regressive assimilation as follows:

국립 /kuk/ + /lip/ → kuŋ.lip (regressive nasalization) → kuŋ.nip (progressive nasalization)

From the observations on Korean, one might anticipate similar assimilation to happen in languages like Southern Min, since it allows all the syllables described in the derivation above. Comparing the phonological phenomena in two languages will give us clues to distinguish phonological rules that are universal from the language-specific ones.

**Hokkien** (Chinese: 福建話 *Fújiànhuà*; POJ: *Hok-kiàn-oē*) is a mainstream Southern Min dialect group spoken throughout the Southern part of Fujian Province in Southeastern China, Taiwan and Southeast Asia, originated from southern Fujian. **Taiwanese** (Chinese: 臺灣語 *Táiwānyǔ*; POJ: *Tâi-oân-gí*), or **Taiwanese Hokkien**, is a branched-off variant of Hokkien spoken natively by about 70% of the population of Taiwan. On the other hand, the official standard language in Republic of China is Taiwanese Mandarin (Chinese: 國語; pinyin: *Guóyǔ*) which has been established as the sole language to be used for education. As a result of the standard language policies, Taiwanese Hokkien has become intrinsically tied into only a few facets of society and is expected to become increasingly marginalized over the next 50 years.

	labial		coronal		dorsal		glottal		
<b>nasal</b>		m		n		ŋ			
<b>stop</b>	p	p <sup>h</sup>	b	t	t <sup>h</sup>	k	k <sup>h</sup>	g	ʔ
<b>affricate</b>				ts	ts <sup>h</sup>	dz			
<b>fricative</b>				s				h	
<b>lateral</b>					l				

	front	central	back							
<b>high</b>	i	ī		u	ū	<b>diphthongs</b>	ia	io	iu	ai
<b>mid</b>	e	ē	o	ɔ	õ		ua	ue	ui	au
<b>low</b>		a	ã			<b>triphthongs</b>	iau		uai	

**Table 1.** Phonemic inventory of Taiwanese Hokkien.  
 (a) Consonants (b) Vowels (c) Diphthongs and triphthongs

Taiwanese Hokkien has eighteen phonemic consonants and all of them except /ʔ/ can occur as a syllable onset. Labial consonants are bilabial and dorsal consonants are velar. When coronal affricates and fricative are followed by [i] or [ī], they are realized as alveolo-palatals, [tɕ, tɕ<sup>h</sup>, dʒ, ɕ]. Otherwise, coronal consonants are alveolar. Unlike Mandarin, there exists a distinction between voiced and voiceless obstruents, forming tripartite series of stops and affricates—plain, aspirated, and voiced. In the coda position, only nasals [m, n, ŋ] and plain stops [p, t, k] can occur, and, just like Korean, stops at the coda position are unreleased. There are six oral vowels and five nasal

vowels. They are combined to create eight diphthongs and two triphthongs. There are five tonal contours with extensive tone sandhi rules. Syllables consist maximally of an onset consonant, a vowel, a coda consonant, and a tone.

It is well established that the coda stops are subjected to the full assimilation when followed by the liquid /l/ in Taiwanese. The same word that is used above in the sample derivation of Korean is pronounced as [kollip], while its underlying form is /kɔk+lip/. We can observe that the coda consonant /-k/ has been fully assimilated to the /l/ and become a part of a geminate. This surface form is very different from Korean, showing that two languages can have different phonological rules even when they have strikingly similar consonantal inventories and syllable structures.

This report will mainly focus on the coda stops /-p, -t, -k/ in Taiwanese Hokkien. All the allophonic variations of these consonants will be carefully observed and analyzed based on the features and rule-based theories in order to investigate the universality lying behind the assimilations.

## 2 Data

Below data were acquired from two female Taiwanese consultants, born in 1994 and 1995.<sup>2</sup> They are native to Taiwanese Mandarin, with full ability to understand their parents' Hokkien, but without native-like fluency in speaking the language. The consultants were ignorant of any of the Hokkien orthographies, so Mandarin Chinese translations were given along with Taiwanese words written in Hân-lô<sup>3</sup>. Tonal marks are all eliminated since they are not the interest of this report. Geminate consonants are transcribed as [CC] instead of [C:] to explicitly demonstrate the allophonic segments.

1.	pm > mm	入 /dzip/ [dzip <sup>˧</sup> ]	+ 門 /mŋ/ [mŋ]	→ 入門 [dzimmmŋ]	'beginning'
2.	tm > nm	這 /tsit/ [tɕit <sup>˧</sup> ]	+ 馬 /ma/ [ma]	→ 這馬 [tɕinma]	'now'
3.	kn > ɲn	學 /hak/ [hak <sup>˧</sup> ]	+ 年 /ni/ [ni]	→ 學年 [haɲni]	'grade'
4.	tp > pp	實 /tsat/ [tsat <sup>˧</sup> ]	+ 腹 /pak/ [pak <sup>˧</sup> ]	→ 實腹 [tsappak <sup>˧</sup> ]	'strong'
5.	kp > pp	北 /pak/ [pak <sup>˧</sup> ]	+ 片 /piŋ/ [piŋ]	→ 北片 [pappiŋ]	'northern'
6.	pt > tt	十 /tsap/ [tsap <sup>˧</sup> ]	+ 七 /ts <sup>h</sup> it/ [tɕ <sup>h</sup> it <sup>˧</sup> ]	→ 十七 [tsattɕ <sup>h</sup> it <sup>˧</sup> ]	'seventeen'
7.	kt > tt	六 /lak/ [lak <sup>˧</sup> ]	+ 十 /tsap/ [tsap <sup>˧</sup> ]	→ 六十 [lattsap <sup>˧</sup> ]	'sixty'
8.	pk > kk	十 /tsap/ [tsap <sup>˧</sup> ]	+ 九 /kau/ [kau]	→ 十九 [tsakkau]	'nineteen'
9.	tk > kk	一 /tsit/ [tɕit <sup>˧</sup> ]	+ 寡 /kua/ [kua]	→ 一寡 [tɕikkua]	'a little'
10.	ks > ts	熟 /sik/ [cik <sup>˧</sup> ]	+ 視 /sai/ [sai]	→ 熟視 [citsai]	'to know'
11.	pl > ll	十 /tsap/ [tsap <sup>˧</sup> ]	+ 六 /lak/ [lak <sup>˧</sup> ]	→ 十六 [tsallak <sup>˧</sup> ]	'sixteen'
12.	tl > ll	骨 /kut/ [kut <sup>˧</sup> ]	+ 力 /lat/ [lat <sup>˧</sup> ]	→ 骨力 [kullat <sup>˧</sup> ]	'diligent'
13.	kl > ll	國 /kɔk/ [kɔk <sup>˧</sup> ]	+ 立 /lip/ [lip <sup>˧</sup> ]	→ 國立 [kollip <sup>˧</sup> ]	'national'
14.	kb > bb	目 /bak/ [bak <sup>˧</sup> ]	+ 眉 /bai/ [bai]	→ 目眉 [babbai]	'eyebrow'
15.	pg > gg	十 /tsap/ [tsap <sup>˧</sup> ]	+ 月 /gue/ [gue]	→ 十月 [tsaggue]	'October'
16.	tdz > ddz	一 /tsit/ [tɕit <sup>˧</sup> ]	+ 日 /dzit/ [dzit <sup>˧</sup> ]	→ 一日 [tɕiddz <sup>˧</sup> it <sup>˧</sup> ]	'one day'
17.	p > b	蛤 /kap/ [kap <sup>˧</sup> ]	+ 仔 /a/ [a]	→ 蛤仔 [kaba]	'frog'
18.	t > l	彼 /hit/ [hit <sup>˧</sup> ]	+ 個 /e/ [e]	→ 彼個 [hile]	'that'
19.	k > g	粟 /ts <sup>h</sup> ik/ [ts <sup>h</sup> ik <sup>˧</sup> ]	+ 仔 /a/ [a]	→ 粟仔 [ts <sup>h</sup> iga]	'rice'

### 3 Analysis

#### 3.1 Nasal Assimilation

The data 1–3. give us clear examples in which coda stops /p, t, k/ turn into their nasal counterparts before a nasal consonant. Consequently, /p, m/, /t, n/, and /k, ŋ/ are neutralized in pairs.

(1) **Nasal Assimilation (NA)**

$/p, t, k/ \rightarrow [ + \text{NASAL} ] / - \left[ \begin{array}{c} \text{C} \\ + \text{NASAL} \end{array} \right]$   
*A /p, t, k/ that immediately precedes a nasal consonant is nasalized.*

p	m	t	n	k	ŋ	UR
	m		n		ŋ	SR

This can be formularized as in (1). Note that /p, t, k/ will not be grouped using features at this stage, as it is unsure which natural class is triggered by the rule above for now. Say, [– SONORANT] or [– DELAYED RELEASE], or even a [+ CONSONANTAL] are possible options for the left side of (1).

Let’s compare this with well-known Korean examples:

입문 /ip/ + /mun/ → [immun]      학년 /hak/ + /njʌn/ → [hʌŋnjʌn]

After consonant-cluster simplification step, there are only three obstruents left, /p, t, k/. These obstruents are subjected to a same kind of nasal assimilation when followed by a nasal.

(2) **Korean Nasal Assimilation**

$/p, t, k/ \rightarrow [ + \text{NASAL} ] / - \left[ \begin{array}{c} \text{C} \\ + \text{NASAL} \end{array} \right]$

#### 3.2 Place Assimilation

When a following consonant is an obstruent, /p, t, k/ assimilates in place of articulation to the following consonant, as in 4–10. They are neutralized into a single phoneme, based on the following segment. This happens only before a stop, but also an affricate (6–7.) and a fricative (10.).

p	t	k	UR
p or t or k			SR

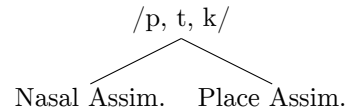
A similar phenomenon is observed in Korean, but only in fast speech.

북방 /puk/ + /paŋ/ → [pukpaŋ] ( → [puppaŋ] in fast speech)  
 불박이 /put<sup>h</sup>/ + /pak.i/ → [putpaŋi] ( → [puppaŋi] in fast speech)

Note that the place assimilation in Taiwanese does *not* co-occur with nasal assimilation. This can be formularized in two different ways.

(3) **Place Assimilation (PA, before obstruents)**

$/p, t, k/ \rightarrow [ \alpha \text{ PLACE} ] / - \left[ \begin{array}{c} - \text{SONORANT} \\ \alpha \text{ PLACE} \end{array} \right]$   
*A /p, t, k/ is assimilated in place of articulation to a following obstruent.*



In (3), PA is applied in complementary situation with NA. However, there is no explanation why only [– SONORANT] segments are triggering PA.

- (4) **Place Assimilation** (PA, before any consonant) /p, t, k/  

$$/p, t, k/ \rightarrow [ \alpha \text{ PLACE } ] / - \left[ \begin{array}{c} \text{C} \\ \alpha \text{ PLACE} \end{array} \right]$$
Nasal Assim.  
*A /p, t, k/ is assimilated in place of articulation to a following consonant.* Place Assim.

2. ‘now’	3. ‘grade’		2. ‘now’	3. ‘grade’	
/tsit+ma/	/hak+ni/	UR	/tsit+ma/	/hak+ni/	UR
n	ŋ	Nasal Assimilation	p	t	Place Assimilation
—	—	Place Assimilation	m	n	Nasal Assimilation
[tʃinma]	[haŋni]	SR	*[tʃimma]	*[hanni]	SR

Here, the rule is modified to eliminate the unnaturality to give (4). In this case, rule ordering is required because NA (1) and PA (4) have overlapping environments. By sample derivations above, it is concluded that NA must precede PA in order to block the full assimilation before a nasal consonant. In above cases, NA *bleeds* PA, as the application of NA creates a context in which PA can no longer apply. This modified version of PA is coherent with the observations (not presented in this report) that coda nasals are not subjected to PA.<sup>4</sup>

### 3.3 Lateralization

The previously reported full assimilation to /l/ is shown in 11–13. This is formularized as below:

- (5) **Lateralization** /p, t, k/  

$$/p, t, k/ \rightarrow l / \_l$$


p	t	k	UR
l			SR

  
*A /p, t, k/ is fully assimilated to a following /l/.*

This rule cannot find its counterpart in Korean. Examples like 국립 /kuk+lip/ [kuŋ.nip̚] contain a similar environment, but follow the two subsequent rules described in (6) and (7).<sup>5</sup>

- (6) **Korean Regressive Nasal Assimilation** (extended version of (2))  

$$[ - \text{SONORANT} ] \rightarrow [ + \text{SONORANT} ] / - \left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \end{array} \right]$$
- (7) **Korean Progressive Nasal Assimilation**  

$$\left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \end{array} \right] \rightarrow [ + \text{NASAL} ] / \left[ \begin{array}{c} \text{C} \\ + \text{NASAL} \end{array} \right] -$$

Then, is the rule (5) a language-specific rule that exists uniquely in Taiwanese? Is it impossible to unify (5) with (1) to make a rule like (6) as in Korean?

- (8) **\*Hypothetical Assimilation Rule** ((1) + (5))  

$$[ - \text{SONORANT} ] \rightarrow \left[ \begin{array}{c} + \text{SONORANT} \\ \alpha \text{ NASAL} \end{array} \right] / - \left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \\ \alpha \text{ NASAL} \end{array} \right]$$

Rule (8) is a hypothetical unification of (1) and (5). The rule seems satisfyingly adequate, nonetheless, there are some problems underlying in this rule. If /p/ or /k/ is subjected to (8), it becomes a liquid with its place feature remains unchanged. This might be fixable by adding place feature assimilation to (8), but, as described below, nasal assimilation *blocks* place assimilation. This ambiguity in dealing with place feature makes (8) unreliable. Then, what is the nature of (5)? Why is /l/ so special, triggering both sonorant assimilation and place assimilation, which cannot occur together in other environments? This will be discussed later.

### 3.4 Voicing Assimilation

In fact, /l/ is not the only consonant that triggers full assimilation. If a /p, t, k/ is followed by a voiced stop, which there are only two in Taiwanese, it is assimilated in both place of articulation and voicing, as shown in 14–15. Similar alternation happens before the only voiced affricate /dʒ/ too, as in 16. But the coda stops are not fully assimilated since Taiwanese does not allow an affricate at the coda position. Instead, they are neutralized into [d] as a part of geminate [dʒ:]. This can be formularized as below:

(9) **Voicing Assimilation (VA)**

$$/p, t, k/ \rightarrow \left[ \begin{array}{c} + \text{VOICE} \\ \end{array} \right] / - \left[ \begin{array}{c} C \\ + \text{VOICE} \end{array} \right]$$

A /p, t, k/ is assimilated in voicing to a following voiced consonant.

p	t	k	UR
b	or d	or g	SR

(10) **Rule Ordering**

Nasal Assimilation  $\gg$  Place Assimilation  $\gg$  Voicing Assimilation

The rule ordering should be like (10), supported by the evidence from sample derivations.<sup>6</sup>

### 3.5 Intervocalic Alternation

Allophones like [b, g] are also found in intervocalic positions. If a coda /p, k/ is followed by an onset-less syllable, it is voiced, as shown in 17 and 19. On the other hand, it is striking that a coda /t/ becomes [l] in the same environment, as in 18.

(11) **Intervocalic Alternation (IA)**

a. p, k  $\rightarrow$   $\left[ \begin{array}{c} + \text{VOICE} \\ \end{array} \right] / \text{V\_V}$   
 b. t  $\rightarrow$  [l] / V\_V

p	t	k	UR
b	l	g	SR

Should the left side of (11a) be grouped as  $[- \text{SONORANT} - \text{CORONAL}]$ ? That would be absurd since it is very unusual to imagine an intervocalic voicing rule—which is universal—to be place-specific. Further discussion to unify these (somewhat random) rules presented in (1), (4), (5), (9), and (11) is described in the next section.

## 4 Discussion

So far, we have formularized five rules that are applied to the syllable-coda stops, /p, t, k/, with an ordering that can be summarized as in (12).

(12) Lateralization  $\leftarrow$  /p, t, k/  $\rightarrow$  Nasal Assim.  $\gg$  Place Assim.  $\gg$  Voicing Assim.  
 $\searrow$  Intervocalic Alteration

Henceforth, I will argue that (i) Taiwanese /l/ should be analyzed as a voiced stop /d/, and (ii) the underlying representation of the coda stops are voiced /b, d, g/, not voiceless /p, t, k/.<sup>7</sup> This way, we can simplify the rules above, and delete the rules that were believed to be language-specific to Taiwanese.

### 4.1 Phonemic status of /d/

The first step to minimalize (12) is to incorporate Lateralization rule into the series of assimilation rules. Integrating (12) into NA was already tried and failed. Note that the consonants that trigger full assimilation are all the stops /p, t, k, b, g/ and so-called /l/. This appeals us to bundle up the six phonemes into a natural class. Moreover, assuming that /p, t, k/ constitute a natural class,

their intervocalic allophones /b, l, g/ are highly likely to constitute a natural class, too. Since there is a vacancy for the coronal voiced stop in the phonemic inventory based on the traditional analysis, postulating that /l/ is actually /d/ will increase the structural symmetry of the inventory.

The new analysis where /l/ is replaced by /d/ give rise to multiple changes in the rules we made. First, Lateralization rule described in (5) is no longer needed because it can be derived by a consequent application of PA and VA. Second, since there is no liquid in the underlying phonemes, nasals are the only sonorants. This allows us to revise NA in (1) as identical to Korean Regressive NA in (6). Learning from the Korean rule, we can now group the starting phonemes as [− SONORANT]. Third, IA in (11) can be now integrated into VA, because both are voicing rules triggered by a following segment (a voiced consonant in VA, a vowel in IA). New sets of rules can be described as in (13–15). (Compare (13) with (6).) The rule ordering stays the same.

- (13) **Nasal Assimilation** (revised version of (1))

$$[ - \text{SONORANT} ] \rightarrow [ + \text{SONORANT} ] / - \left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \end{array} \right]$$

- (14) **Place Assimilation**

$$[ - \text{SONORANT} ] \rightarrow [ \alpha \text{ PLACE} ] / - \left[ \begin{array}{c} \text{C} \\ \alpha \text{ PLACE} \end{array} \right]$$

- (15) **Voicing Assimilation** (unified version of (9) and (11), to be further revised)

$$[ - \text{SONORANT} ] \rightarrow [ + \text{VOICE} ] / - [ + \text{VOICE} ]$$

## 4.2 Phonetic realization of /d/

There might be a criticism that this analysis does not properly represent the phonetic realization of the phoneme, therefore too *abstract*. However, some aspects in the phonetic surface form that validate our assumption. First, intervocalic /d/ is realized more as an alveolar lateral flap [ɺ] than as an approximant [l]. (e.g. 彼個 [hiJe]) It is very common to have a flap as an allophone of a stop as in English. (e.g. *header* [ˈhɛɾɚ]) Moreover, there was a speaker variation (presumably dialectal<sup>8</sup>), where /d/ was realized as [ᵐd] in word-initial positions, and [d~ɾ] in intervocalic positions, when it is not followed by a low vowel. This voiceless prenasalization of the initial /d/ was also shared by other voiced stops in this variation, i.e. when narrowly transcribed, word-initial /b, d, g/ were [ᵐb, ᵐd, ᵐg], respectively. From the observations, an *ad hoc* rule of /d/ realization can be made.

- (16) **/d/ Realization**

/d/ is realized as a stop or /l/ word-initially, a flap intervocalically, and /l/ when geminated.

#C	VCV	VCCV	speaker(s)
l	l~ɺ	l:	CTL, HYH
ᵐd	d~ɾ	l:	HYH

## 4.3 Historical development of /d/

Another supporting evidence to regard /l/ as /d/ arises from diachronic studies. It is well known that the voiced initials in Southern Min varieties developed from their corresponding nasals /m, n, ŋ/ in Middle Chinese via denasalization, while they are preserved as they were in Sino-Korean. (e.g. 文物 /bun.but/ Kor. 문물 /mun.mul/; 男女 /dam.di/ Kor. 남녀 /nam.njʌ/; 言語 /gian.gi/ Kor. 언어 /ʌn.ʌ/, MK \*/ŋʌn.ŋʌ/) This historical sound correspondence explains us why [l] behaves like other voiced stops in our data regarding to assimilations. As the expected denasalized reflex of \*/n/ is /d/, it is plausible to use /d/ as an underlying phoneme in the diachronic point of view.

## 4.4 Voicing or Devoicing?

Let's get back to the voicing rule (15). This rule is defective because it is overapplied to all the intervocalic voiceless obstruents, no matter which part of syllable structure the segment is from. For example, 阿爸 /a.paʔ/ 'father' is realized as [a.paʔ]. But the rule (15) predicts voicing of

intervocalic /p/ to give \*[a.baʔ]. We can correct the environment of the rule to  $\_\_\$ [ + \text{VOICE} ]$ , but it is very unnatural to hypothesize that the segments are voiced only when there is a syllable boundary between a target and a trigger. This issue can be eliminated by assuming that the underlying phonemes of the syllable coda stops as voiced /b, d, g/ along with a set of devoicing rules that are applied word-finally and when adjacent to a voiceless segment without changing the rule ordering as in (17) and (18).<sup>9</sup> This also explains the distribution of voiced obstruents in syllable-initial positions. In Taiwanese syllables, voiced obstruents or /l/ is never followed by a nasal vowel or a syllabic nasal consonant, e.g. there is no syllable such as \*[bã] or \*[bŋ]. 門 ‘door’ can be read either [mŋ] or [bun], the former being unaffected by the denasalization.

(17) **Devoicing**

$$[ - \text{SONORANT} ] \rightarrow [ - \text{VOICE} ] / \_\_\{ [ - \text{VOICE} ] , \# \}$$

*An obstruent is devoiced before a voiceless segment and word-finally.*

(18) **Rule Ordering**

Nasal Assimilation  $\gg$  Place Assimilation  $\gg$  Devoicing

This question, asking either there is a voicing or devoicing for the syllable-final stops, might not be a question in languages that do not have VOICE distinction in stops. For example, Korean, Cantonese (Yue Chinese), or Hakka Chinese has no phonemic voiced obstruent but still retains syllable-final stops. All of them have varying degree of intervocalic voicing of these stops but there is no need to use voiced stops as their underlying forms. But, in Taiwanese (and other Min varieties), intervocalic voicing of stop consonants result in allophones that belong to other (voiced) phonemes, making it unnatural to group these syllable-final stops with voiceless initials, which do not undergo intervocalic voicing rule in order to be distinguishable from voiced initials.

## 5 Conclusion

In this report, two arguments were made, that the phoneme previously analyzed as /l/ is in fact a voiced stop /d/ and that the underlying representation of the syllable coda stops are voiced /b, d, g/. The former is supported by the phonological symmetry, phonetic realizations, and the historical development of the phoneme /d/, while the latter is supported by the comparison of intervocalic surface forms of syllable-final stops with their corresponding syllable-initial stops.

Based on these arguments, it was confirmed that the full assimilation to (so-called) /l/ is not a part of sonority assimilation as it is in Korean, but it is a part of place assimilation. Not only its peculiar assimilation-triggering aspect, but also its unique realization and distribution were explained by handling it as a voiced stop. Consequently, it was able to formulate three sequential assimilation rules from various sporadic-looking phenomena, namely, Nasal Assimilation, Place Assimilation, and Devoicing. Especially, NA and PA were found to be strikingly similar to those of Korean, inferring some degree of phonological universality underlying them.

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## Appendix

### Abbreviations

Kor.	Korean
IA	Intervocalic Alteration
MC	Middle Chinese
NA	Nasal Assimilation
PA	Place Assimilation
POJ	Pêh-ōe-jī
SR	surface representation
UR	underlying representation
VA	Voicing Assimilation

### Notes

1. Pêh-ōe-jī (POJ; Chinese: 白話字 Bái huà zì) is an orthography used to write variants of Southern Min Chinese, developed by Western missionaries working among the Chinese diaspora in Southeast Asia in the 19<sup>th</sup> century and refined by missionaries working in Xiamen and Tainan. It uses a modified Latin alphabet and some diacritics to represent the spoken language.
2. See Figure 1 for the hometown of the consultants.
3. Hàn-lô (Chinese: 漢羅 Hàn-Luó) is a mixed orthography of Chinese characters (Chinese: 漢字 hàn zì) and Latin alphabets for Southern Min. Since not all Min words have known or standardized Chinese characters, those words are written in POJ or Taiwanese Romanization System (Tâi-lô). Below is an example where a Taiwanese phrase ‘good morning’ is written in three methods:

Chinese character	勢早
Hàn-lô	gâu-早
Pêh-ōe-jī	gâu-chá

4. There is an exception for /n/. Unlike other coda nasals, /n/ is often subjected to PA as in 文明 /bun+biŋ/ [bumbiŋ] and 堅固 /kian+kɔ/ [kiɛŋkɔ], speaking based on the observations. This might be better analyzed using Optimality Theory, by adjusting the preservation constraints of non-coronals behind those of coronals. This subject is way beyond this report, hence will be ignored here.
5. Traditional analysis posits the progressive nasal assimilation before the regressive one.

국립 /kuk/ + /lip/ → kuk.nip (progressive nasalization) → kuŋ.nip (regressive nasalization)

However, this analysis is wrong because an obstruent /k/ is not appropriate to be a nasal assimilation trigger. Jun (2000) suggests further experimental evidences that there exists a preliquid nasalization in Korean, i.e. stops like /p, t, k/ are subject to nasalization when they are followed by nasals and liquids. It can be formulated as below:

(19) **Korean Regressive Nasal Assimilation**

$$\begin{array}{l}
 \text{a. } \left[ \begin{array}{c} \text{C} \\ - \text{NASAL} \end{array} \right] \rightarrow \left[ + \text{NASAL} \right] / - \left[ \begin{array}{c} \text{C} \\ + \text{NASAL} \end{array} \right] \\
 \text{b. } \left[ \begin{array}{c} \text{C} \\ - \text{NASAL} \end{array} \right] \rightarrow \left[ + \text{NASAL} \right] / - \left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \\ - \text{NASAL} \end{array} \right]
 \end{array}$$

(20) **Korean Progressive Nasal Assimilation**



$$\left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \\ - \text{NASAL} \end{array} \right] \rightarrow [ + \text{NASAL} ] / \left[ \begin{array}{c} \text{C} \\ + \text{NASAL} \end{array} \right] -$$

(19a) and (19b) can be unified as nasals and liquids as  $\left[ \begin{array}{c} \text{C} \\ + \text{SONORANT} \end{array} \right]$ , because they are the only sonorant consonants in Korean. Thus, these rule can be further simplified to give (6) and (7).

6. If VA precedes PA, VA will bleed PA because its resulting phonemes /b, d, g/ are not the subject of VA.

14. 'eyebrow'	15. 'October'		14. 'eyebrow'	15. 'October'	
/bak+ba <sub>i</sub> /	/tsap+g <sub>ue</sub> /	UR	/bak+ba <sub>i</sub> /	/tsap+g <sub>ue</sub> /	UR
—	—	Nasal Assim.	—	—	Nasal Assim.
p	k	Place Assim.	g	b	Voicing Assim.
b	g	Voicing Assim.	—	—	Place Assim.
[babbai]	[tsagg <sub>ue</sub> ]	SR	*[bagbai]	*[tsabg <sub>ue</sub> ]	SR

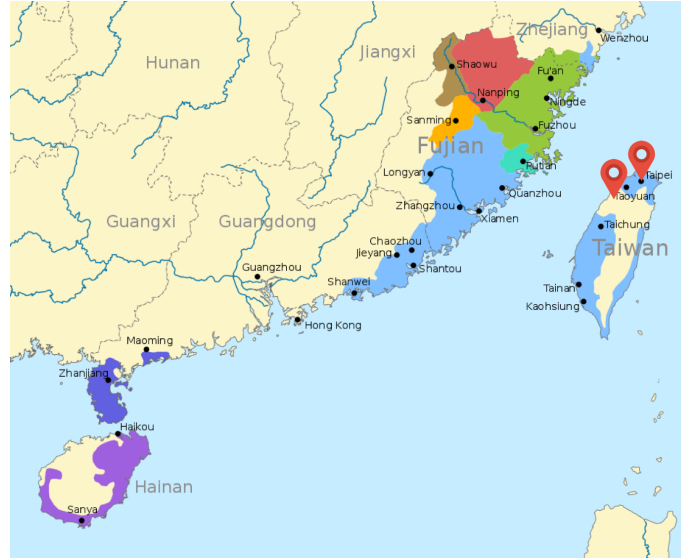
7. These claims are consistent with Lin (2012), although they are developed independently.

8. Note that this dialectal variation /d~l/ is also found in Sioux languages (a group of language varieties including one widely known as Lakota language), where Santee-Sisseton and Yankton-Yanktonai dialects have /d/, which Teton dialect lacks, and Teton has corresponding /l/, which other dialects lack. This is also depicted in their endonyms *Dakota* and *Lakota*.

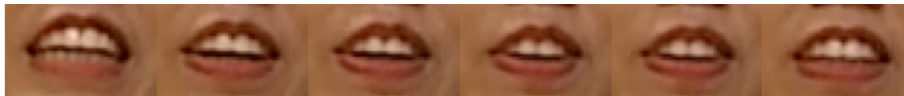
9. Sample derivations are as follows:

1. 'beginning'	4. 'strong'	11. 'sixteen'	14. 'eyebrow'	18. 'that'	
/dzib+m <sub>ŋ</sub> /	/tsad+pag/	/tsab+dag/	/bag+ba <sub>i</sub> /	/hid+e/	UR
m	—	—	—	—	Nasal Assim.
—	b	d	b	—	Place Assim.
—	p k <sup>ʔ</sup>	—	—	—	Devoicing
—	—	l l	—	ɪ	/d/ Realization
[dzimm <sub>ŋ</sub> ]	[tsappag <sup>ʔ</sup> ]	[tsallak <sup>ʔ</sup> ]	[babbai]	[hi.le]	SR

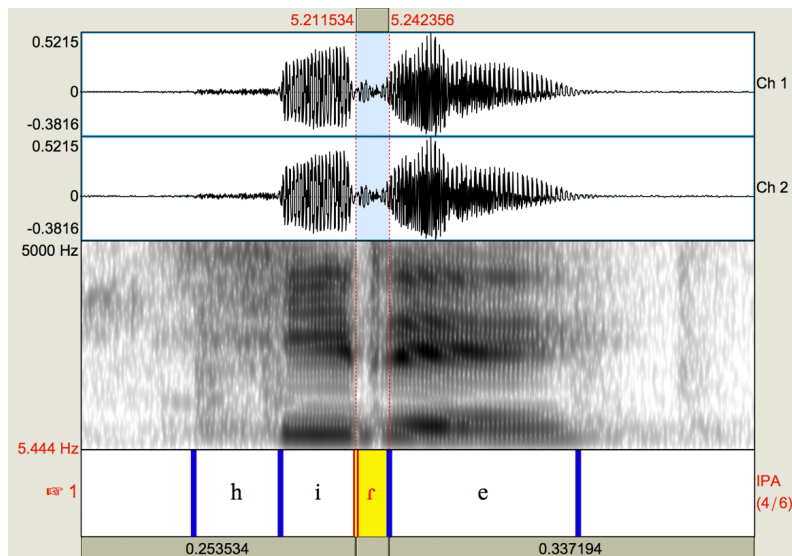
Figures



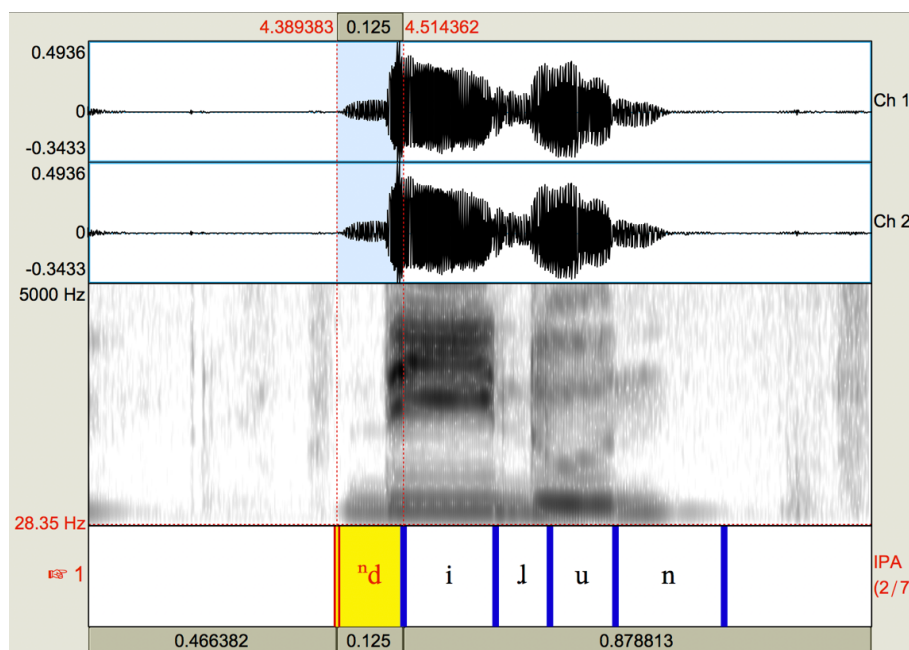
**Figure 1.** Distribution of Min dialectal group in China. Light blue represents the area where Southern Min is spoken. The hometowns of the two consultants, Taipei and Hsinchu, are marked in the map.



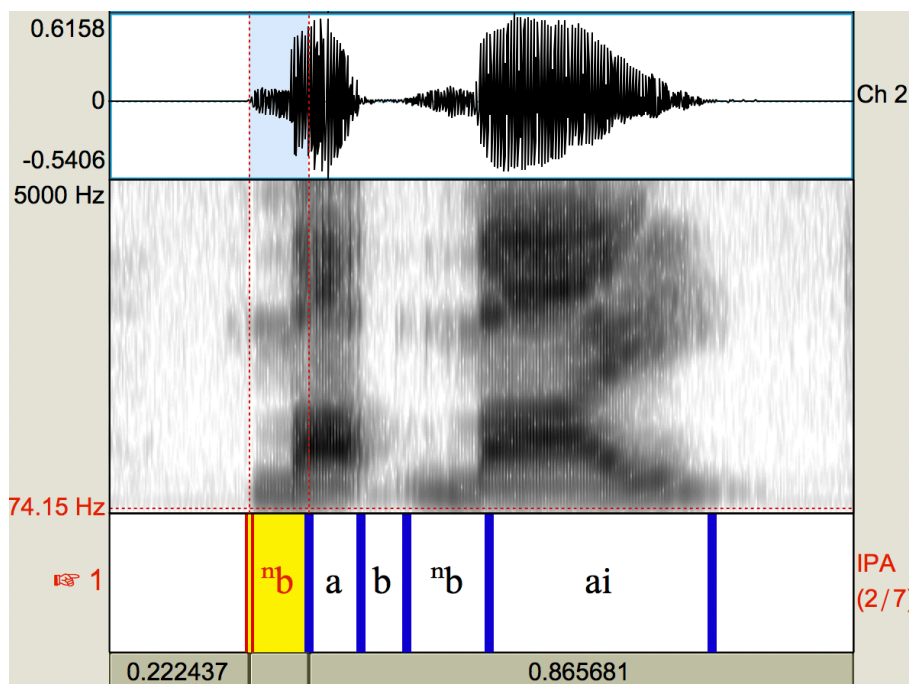
**Figure 2.** Motion capture of the speaker's lips when speaking 十月 [tsagg̊e] 'October'. Time interval = 50 ms. No lip closure observed. Evidence of place assimilation.



**Figure 3.** Spectrogram of 彼個 /hit.e/ [hi.re] 'that' (from hit\_e\_HYH\_1.wav). The amplitude decreases dramatically between the vowels, indicating that this is not an approximant. Instead, a small burst is observed, meaning that this is a flap.



**Figure 4.** Spectrogram of 理論 /li.lun/ [n̥di.lun] ‘theory’ (from various\_L.wav)  
 The first realization of /l/ is a voiced stop with prenasalization. A nasality is observed before the burst and the frequency is lower than that of a voicing bar. The second realization of /l/ is a flap, as it was in Figure 3, but this time, a strong laterality is observed, as the amplitude is a bit stronger and dramatic change of the F2 line is shown between the vowels.



**Figure 5.** Spectrogram of 目眉 /bak.bai/ [n̥bab.n̥bai] ‘eyebrow’ (from 14\_bak\_bai.wav)  
 A strong prenasalization is observed before each syllable-initial /b/’s.