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Onset Voicing and Tone Distribution in the Taiwanese Lexicon

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This study examines the relationship between onset voicing and distribution of tones in the Taiwanese (Taiwan Southern Min) lexicon by looking at whether onset-tone association still follows the prediction of the phonetics of tonogenesis: syllables with voiceless onsets are more likely to have a high tone, and syllables with voiced onsets are more likely to have a low tone. By using the observed-over-expected metric (e.g. Frisch & Zawaydeh, 2001) from counting lexical items in a dictionary, the analysis reveals that for the high-level, high-falling, and the mid-rising tones, the tone-onset association follows the prediction of the phonetics of tonogenesis, although the mid-falling tone does not exhibit the predicted association. The low-level tone, which used to be a high tone, is more positively associated with voiced onset, showing a consistent association with its synchronic tonal value. On the other hand, the checked tones, which also had a tonal flip since earlier stages of Min, exhibit a tone-onset association that conform to what their diachronic tonal values would predict.

1. Introduction

This paper aims to examine the relationship between onset voicing and tone distribution in the Taiwanese (Taiwan Southern Min) lexicon, as one step towards a better understanding of the synchronic phonotactics of this language. In particular, predictions made by diachronic and synchronic tonal values in connection to onset voicing are compared.

Taiwanese is a tone language featuring seven lexical tones. In the "checked syllables", which are syllables closed by a plosive coda such as /p/, /t/, /k/, or /ʔ/, there are the high-checked tone and the low-checked tone. In other syllable types, there are five tones, namely the high-level tone, the high-falling tone, the mid-falling tone, and the mid-rising tone, and the low-level tone. There are gaps for the combination of tones and syllable types: not all syllable types in Taiwanese carry all possible tones they can carry. For example, /ba/ only carries the mid-rising and low-level tones.

In the present study, I focus on the distribution of attested combinations between syllable types and tones, following both phonetic observations about F0 perturbations after voiceless and voiced onsets (higher F0 after voiceless stops, e.g., in Ohde 1984) and the related claims on tonogenesis (e.g., Hombert et al. 1979): It is believed that lexical tones arise through tonogenesis driven by F0 perturbations following different types of

onsets. Voiceless stops cause a higher F0 at the beginning of the vowel than voiced onsets do. Lexical tones, at least the difference in tonal registers, then arise through a reanalysis of the phonetic side effect as a phonological contrast.

Two claims about the tonal development in Min are of interest. First, voiced stops in early Min have become voiceless, potentially as a by-product of the reanalysis of a voicing contrast into a tonal contrast, and the present-day voiced stops arose through other sources such as nasal stops (Norman, 1988, 1973). Assuming no drastic change has happened to alter the tone distribution on syllable types, syllables with voiceless onsets in the synchronic Taiwanese lexicon should have a higher probability of having high tones than syllables with voiced onsets, which through the same process of tonogenesis should only acquire low tones. In other words, syllable types with voiceless onsets should be more likely to carry high tones than syllable types with voiced onsets. An investigation on how well onset voicing predicts the distribution of tones could shed light on the issue of whether the result of phonetically motivated diachronic changes maintains the relationship between synchronic phonological patterns and phonetic motivations.

Another interesting claim is that in two of the tonal classes[1], the high and the low tones underwent a change in tonal register: the tone that has been described as high tone historically has become a low-level tone in contemporary Taiwanese. The same is also true for the two checked tones, as there is a flip in tonal values from the historically high and low tones (Norman, 1973, 1974; Handel, 2003), the first two columns of Table 1.

Table 1. Diachronic and synchronic tones in Taiwanese

Diachronic class & tonal register	Tonal value in Taiwanese	Prediction on tone-onset association	
		Diachronic	Synchronic
*A, high	High-level	[−voice]	[−voice]
*A, low	Mid-rising	[+voice]	[+voice]
*B, high	High-falling	[−voice]	[−voice]
*B, low	(absent)	NA	NA
*C, high	Low-level	[−voice]	[+voice]
*C, low	Mid-falling	[+voice]	[+voice]
*D, high	Low-checked	[−voice]	[+voice]
*D, low	High-checked	[+voice]	[−voice]

[1] The tonal classes refer to the four categories that describe the shapes of tones in Middle Chinese. *A refers to level tones, *B refers to rising tones, *C refers to falling tones, and *D refers to checked tones.

Following these two claims, if the distribution of tones in Taiwanese still follows the diachronic development, there should be a positive association between voiceless onsets and the diachronic high tones: the high-level, high-falling, and, crucially, the low-level and low checked tones. As shown in Table 1, diachronic and synchronic tonal values would make different predictions on onset-tone associations. Whether the Taiwanese lexicon supports the prediction made by diachronic tonal values or synchronic ones is the main research question of this paper.

The wider implication of this paper concerns the role of synchronic and diachronic explanations in phonological grammars or lexicons. Two different views make two different predictions concerning the results of the present study. One of them sees the synchronic phonological grammar as results of language changes that are motivated by channel bias, which includes phonetic and perceptual factors (e.g., Blevins, 2004; Mielke, 2008). Under this view, the current relationship of the voicing feature and the tonal feature in Taiwanese should be independent of the tonal development other than the remnant of sound change. In other words, it is possible for low tones to associate more with voiceless stops. A different view is the relationship between onset voicing and tone may be somehow encoded in the Universal Grammar, which in turns constrains sound change. Under this view, high tones should be associated with voiceless onsets in the contemporary lexicon no matter regardless of the diachronic facts. If this is the case, then the onset-tone association may be seen as one instance of markedness asymmetry that not totally explainable by diachronic changes caused by performance factors (see de Lacy and Kingston, 2013), and it is thus motivated to posit markedness constraints to account for the asymmetry (e.g., *[+voice]$V^{\text{high-tone}}$ and *[−voice]$V^{\text{low-tone}}$).

2. Method

The data used in this study were extracted from a dictionary of Taiwanese downloaded from the Github repository[2] of the MoeDict project[3]. The MoeDict project aimed to build better interfaces to the government-provided language resources, namely the official online dictionaries of Mandarin Chinese, Taiwanese, and Hakka from the Ministry of Education in Taiwan. The downloaded dictionary contained a list of lexical entries written in Chinese characters along with their pronunciations coded in the Romanized writing system for Taiwanese. The pronunciations listed in the dictionary were taken as the attested syllable-tone combinations in the Taiwanese lexicon.

The dictionary was transformed by tallying the tonal categories each syllable type (e.g., pa, ba, nĩ, etc) can carry. Six syllable-level phonological features were annotated, including onset voicing, onset aspiration, onset nasality, vowel nasality, vowel length, and coda nasality. For the present analysis, only onset voicing was used.

[2] https://github.com/g0v/moedict-data-twblg/tree/master/raw
[3] https://www.moedict.tw

The aim of the analysis was to see whether the presence of each tone on a given syllable type is associated with onset voicing. This was carried out by investigating the observed/expected (O/E) value of the frequency of syllable types that contains a voiced onset and lacks a given tone. An O/E value higher or lower than 1 indicates that the number of syllable types having a particular tone is higher or lower than expected given independent distribution of onset voicing and tone gaps (see e.g. Coetzee and Pater, 2008; Frisch and Zawaydeh, 2001). The statistical significance of the deviation from prediction made by chance was evaluated with Chi-Square tests.

3. Results

For each tonal category, the association between whether the tone is attested and whether the onset is voiced presented with the O/E measurement and a Chi-Square test. Syllable types without onset were excluded from the analysis, as the prediction about their interaction between tonal distribution is less clear. In addition, since the phonetic motivation for the association between onset voicing and F0 arises through interactions between for stops and F0 perturbations, I also ran analysis with syllable types whose onset is a stop so that I could see whether this restricted data set behave differently.

This section is broken down into four subsections, according to whether the diachronic and the synchronic accounts have the same prediction and whether the tones are considered high tones or low tones in a synchronic sense. The results will be reported along with contingency tables showing the distribution of syllable types regarding whether they have voiced or voiceless onsets and whether they can carry a particular tone.

3.1 High-level and high-falling tones:

The high-level and high-falling tones were described as high tones in earlier Min. They also start with a high target in contemporary Taiwanese. This section examines whether they are more likely to co-occur with voiceless onset. Table 2 shows that for the overall dataset, syllables with voiceless onsets are more likely to carry high level tone (O/E = 1.19), whereas syllables with voiced onsets are less likely to carry high-level tone (O/E = 0.44). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 468) = 121.87, p < .00001$]. The positive association between high-level tone and voiceless onsets follows the prediction of both the diachronic and the synchronic account.

Similar results were obtained when the analysis focused on the set of syllable types whose onsets are stops. As shown in Table 3, syllables with voiceless onsets are more likely to carry high level tone (O/E = 1.38), whereas syllables with voiced onsets are less likely to carry high level tone (O/E = 0.20). The association between onset voicing and the distribution of high-level tones may be considered stronger as these two O/E values become more different. The Chi-Square test yielded statistical significance [$\chi^2(1, N = 151) = 71.60, p < .00001$].

Table 2. Association between the high-level tone and onset voicing: overall data[4]

	With high-level tone	Without high-level tone
Voiced onset	38 (85.64) 8.11% / 18.29% O/E = **0.44**	82 (34.35) 17.52% / 7.34 % O/E = 2.38
Voiceless onset	296 (248.36) 63.25% / 53.07% O/E = **1.19**	52 (99.64) 11.11% / 21.29% O/E = 0.52

Table 3. Association between the high-level tone and onset voicing: syllables with plosive onsets

	With high-level tone	Without high-level tone
Voiced onset	6 (30.18) 3.97% / 19.98 % O/E = **0.20**	43 (18.82) 28.48% / 12.46% O/E = 2.28
Voiceless onset	87 (62.82) 57.61% / 41.60% O/E = **1.38**	15 (39.18) 9.93% / 25.95% O/E = 0.38

As for the high-falling tone, the analysis showed that it occurs slightly more than expected with voiceless onsets (O/E = 1.01) and less than expected with voiced onsets (O/E = 0.96). The Chi-Square test did not yield statistical significance [$\chi^2(1, N = 468) = 0.29$, $p = 0.59$]. The full results can be seen in Table 4.

Table 4. Association between the high-falling tone and onset voicing: overall data

	With high-level tone	Without high-level tone
Voiced onset	81 (83.84) 17.30% / 11.91% O/E = 0.96	39 (36.15) 8.33% / 7.72% O/E = 1.07
Voiceless onset	246 (243.15) 52.56% / 51.95% O/E = 1.01	102 (104.85) 21.79% / 22.40% O/E = 0.97

[4] For each cell in the table, the number in the first row without the parenthesis indicates the number of syllable types that (1) has a voiced onset or not and (2) carries a particular tone or not in the Taiwanese lexicon. The number in the parenthesis indicates the expected number given the overall distribution, if there is no dependency between onset voicing and whether a syllable can carry a particular tone. The second row shows the observed and the expected values in percentages. The third row shows the observed-over-expected value.

When the analysis was conducted with the syllable types whose onsets are stops, a stronger positive association between the occurrence of the high-falling tone and onset voicing was observed. The high-falling tone is more likely to occur with voiceless onsets (O/E = 1.09) and less likely with voiced onset (O/E = 0.81). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 151) = 5.02$, $p < 0.05$]. The full results can be seen in Table 5. This positive association of high-falling tone and voiceless stops follows the prediction of both the diachronic and the synchronic account.

Table 5. Association between the high-falling tone and onset voicing: syllables with plosive onsets

	With high-falling tone	Without high-falling tone
Voiced onset	28 (34.40) 18.54% / 22.78% O/E = **0.81**	21 (14.60) 13.91% / 9.67% O/E = 1.43
Voiceless onset	78 (71.60) 51.66% / 47.42% O/E = **1.09**	24 (30.40) 15.89% / 20.13% O/E = 0.79

3.2. Mid-falling and mid-rising tones

This subsection presents analyses the contemporary mid-falling and mid-rising tones, who were also categorized as low-register tone diachronically. Table 6 shows that for the overall dataset, syllables with voiceless onsets are more likely to carry mid-falling tone (O/E = 1.22), whereas syllables with voiced onsets are less likely to carry high-level tone (O/E = 0.37). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 468) = 111.22$, $p < .00001$]. The positive association between mid-falling tone and voiceless stops does not follow the prediction of both the diachronic and the synchronic account.

Table 6. Association between the high-falling tone and onset voicing: overall data

	With mid-falling tone	Without mid-falling tone
Voiced onset	28 (76.41) 5.98% / 16.32% O/E = **0.37**	92 (43.58) 19.66% / 9.31% O/E = 2.11
Voiceless onset	270 (221.58) 57.69% / 47.34% O/E = **1.22**	78 (126.41) 16.67% / 27.01% O/E = 0.62

When the analysis was conducted with the syllable types that have a stop as the onset, similar association between the occurrence of high-falling tone and onset voicing was observed. The mid-falling tone is more likely to occur with voiceless onset (O/E = 1.34) and less likely with voiced onset (O/E = 0.30). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 151) = 54.61$, $p < .00001$]. The full results can be seen

in Table 7. Again, the positive association between mid-falling tone and voiceless stops does not follow the prediction of both the diachronic and the synchronic account.

Table 7. Association between the high-falling tone and onset voicing: syllables with plosive onsets

	With mid-falling tone	Without mid-falling tone
Voiced onset	9 (30.18) 5.96% / 19.99% O/E = 0.30	40 (18.82) 26.49% / 12.46% O/E = 2.13
Voiceless onset	84 (62.82) 55.62% / 41.60% O/E = 1.34	18 (39.18) 11.92% / 25.95% O/E = 0.46

As for the mid-rising tone, the analysis showed that the high-falling tone occurs more than expected with voiced onsets (O/E = 1.15) and less than expected with voiceless onsets (O/E = 0.95). The Chi-Square test yield statistical significance [χ^2(1, N = 468) 7.44, $p < .01$]. The full results can be seen in Table 8. The positive association between mid-falling tone and voiced stops follows the prediction of both the diachronic and the synchronic account.

Table 8. Association between the mid-rising tone and onset voicing: overall data

	With mid- rising tone	Without mid- rising tone
Voiced onset	95 (82.56) 20.29% / 17.64% O/E = **1.15**	25 (37.44) 5.34% / 8.00% O/E = 0.66
Voiceless onset	227 (239.43) 48.50% / 51.16% O/E = **0.95**	121 (108.56) 25.85% /23.19% O/E = 1.11

When the analysis was conducted with the syllable types that have a stop as the onset, similar association was observed. The mid-falling tone is more likely to occur with voiced onset (O/E = 1.11) and less likely with voiceless onset (O/E = 0.95), although the Chi-Square test did not yield statistical significance [χ^2(1, N = 151) = 2.20, $p = .16$]. The full results can be seen in Table 9.

Table 9. Association between the mid-rising tone and onset voicing: syllables with plosive onsets

	With mid- rising tone	Without mid-rising tone
Voiced onset	41 (36.99) 27.15% / 24.50% O/E = 1.11	8 (12.01) 5.29% / 7.95% O/E = 0.66
Voiceless onset	73 (77.01) 48.34% / 50.10% O/E = 0.95	29 (24.99) 19.20% /16.55% O/E = 1.16

3.3. High-checked tone

For the high-checked tone, a synchronic phonetic account would predict that it should be more likely to occur after a voiceless onset. However, this tone is described as having a low tone in early stages, so a diachronic account should predict an association with voiced onsets.

Analysis on the overall data seemed to suggest that the association between the high-checked tone and onset voicing goes in the direction of the diachronic account: it occurs with voiced onsets more than expected (O/E = 1.24) and less than expected with voiceless onsets (O/E = 0.92). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 278) = 9.06$, $p < .01$]. The full results can be seen in Table 10.

Table 10. Association between the high-checked tone and onset voicing: overall data

	With high-checked tone	Without high-checked tone
Voiced onset	55 (44.34) 19.78% / 15.95% O/E = **1.24**	12 (22.65) 4.32% / 8.15% O/E = 0.53
Voiceless onset	129 (139.65) 46.40% / 50.23% O/E = **0.92**	82 (71.35) 29.50% /25.66% O/E = 1.15

Similar results were obtained with analysis on a smaller dataset consisting of only syllables with stop onsets. The high-checked tone occurs with voiced onsets more than expected (O/E = 1.22) and less than expected with voiceless onsets (O/E = 0.90). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 86) = 4.42$, $p < .05$]. The full results can be seen in Table 11.

Table 11. Association between the high-checked tone and onset voicing: syllables with plosive onsets (wrong numbers)

	With high-checked tone	Without high-checked tone
Voiced onset	24 (19.65) 27.9% / 22.85% O/E = **1.22**	2 (6.35) 2.32% / 7.38% O/E = 0.31
Voiceless onset	41 (45.34) 47.68% / 52.73% O/E = **0.92**	19 (14.65) 29.50% /25.66% O/E = 1.15

3.4. Low-level and low-checked tones

Contemporary low-level and low-checked tones were described as high tones in early Min where their tonal value supposedly reflect the phonetic environment on tonogenesis. Following the diachronic prediction, they should be more likely to occur with voiceless stops. On the other hand, a synchronic phonetic account would predict a positive association between these tones and voiced onsets.

For the low-level tone, the synchronic phonetic account made the right prediction on the actual data: low-level tones occur more than expected with voiced onsets (O/E = 1.19) and less than expected with voiceless onsets (O/E = 0.93). The Chi-Square test yielded statistical significance [χ^2(1, N = 468) = 4.42, = 10.09, $p < .01$]. The full results can be seen in Table 12.

Table 12. Association between the low-level tone and onset voicing: overall data

	With high-checked tone	Without high-checked tone
Voiced onset	93 (82.56) 19.87% / 16.71% O/E = **1.19**	27 (37.44) 5.77% / 8.93% O/E = 0.65
Voiceless onset	212 (239.43) 45.29% / 48.46% O/E = **0.93**	136 (108.56) 29.06% /25.90% O/E = 1.12

However, when the analysis was done with the set of syllable types whose onsets are stops, the there was a change of the O/E values: the low-level tone is slightly more likely to occur with voiceless stop onsets (1.01) and less likely with voiced onsets (0.98), although the result of the statistical test was far from reaching significance [χ^2(1, N = 151) = 0.00, $p = .95$]. The results are shown in Table 13.

Table 13. Association between low-level tone and onset voicing: syllables with plosive onsets

	With high-checked tone	Without high-checked tone
Voiced onset	37 (37.64) 24.50% / 24.93% O/E = 0.98	12 (11.35) 7.94% / 7.52% O/E = 1.06
Voiceless onset	79 (78.35) 52.31% / 51.89% O/E = 1.01	23 (23.64) 15.23% / 15.66% O/E = 0.97

The distribution of low-checked tones, just like that of the high-checked tones, follows the prediction of a diachronic account: it occurs more than expected with voiceless onsets (O/E = 1.16) and less than expected with voiced onsets (O/E = 0.49). The Chi-Square test yielded statistical significance [$\chi^2(1, N = 278) = 15.64$, $p < .00001$]. The full results can be seen in Table 14. Similar patterns can be observed with the subset of data where the onsets of syllables are stops, but the Chi-Square test did not yield statistical significance. [$\chi^2(1, N = 86) = 2.59$, $p = .11$]. The results can be seen in Table 15.

Table 14. Association between the low-checked tone and onset voicing: overall data

	With low-checked tone	Without low-checked tone
Voiced onset	14 (28.43) 5.03% / 10.22% O/E = **0.49**	53 (38.56) 19.06% / 13.87% O/E = 0.65
Voiceless onset	104 (89.56) 37.41% / 32.22% O/E = **1.16**	107 (121.44) 38.49% / 43.68% O/E = 0.88

Table 15. Association between low-checked tone and onset voicing: syllables with plosive onsets

	With low-checked tone	Without low-checked tone
Voiced onset	7 (10.88) 8.13% / 12.65% O/E = 0.64	19 (15.12) 22.09% / 17.58% O/E = 1.26
Voiceless onset	29 (25.12) 33.72% / 29.20% O/E = 1.15	31 (34.88) 36.05% / 40.56% O/E = 0.89

4. Discussion and Conclusion

Table 16 summarizes the results and the corresponding predictions that are born out. The high-level, mid-rising, and high-falling tones have not undergone flip of tonal values, and the association with onset voicing follows the prediction based on tonal values. In the other case where diachronic and synchronic predictions converge, the prediction was not borne out: the mid-falling tone is more positively associated with voiceless onsets. One potential account based on synchronic grammar is tone sandhi: when a syllable with mid-falling tone occurs in a constituent-medial position, it undergoes tone sandhi and surface with a high-falling tone. However, the same account cannot easily explain the association of voiceless onsets with the high-level tone, since high-level tone also changes its tone register and became a low-level tone in the sandhi form. An investigation of the frequency of base and sandhi forms of these syllables may be able to shed light on this issue.

Table 16. Overall results on onset-tone association in Taiwanese

Diachronic class & tonal register	Tonal value in Taiwanese	Result (positive association with…)	consistent with which prediction?
*A, high	High-level	voiceless onsets (and stops)	diachronic and synchronic
*A, low	Mid-rising	voiced onsets	diachronic and synchronic
*B, high	High-falling	voiceless stops	diachronic and synchronic
*B, low	(absent)	NA	NA
*C, high	Low-level	voiced onsets	synchronic
*C, low	Mid-falling	voiceless onsets (and stops)	neither
*D, high	Low-checked	voiceless onsets	diachronic
*D, low	High-checked	voiced onsets and stops	diachronic

In the cases where the diachronic and synchronic accounts diverge, the results were mixed. In the case of checked tones, the diachronic prediction proves to be correct: the association between tonal distribution and onset voicing is the reverse of what a synchronic account would explain, and corresponds to the diachronic description on a tonal flip. One potential confound is that the actual pronunciation of checked tones varies widely from dialect to dialect (e.g., Chen, 2009). Given the description based on some other dialect/accent of Taiwanese, the synchronic account may be consistent with the diachronic pattern. The same level of inconsistency is not found for the tones on plain syllables. However, the variations on synchronic account does not discredit the fact the

onset voicing is connected to the diachronic tone values for checked tones. Such tighter connection to diachronic sound change instead of a synchronic phonetic motivation would be related to the wider discussion of how unnatural sound patterns arise in languages, as in the work of Mielke (2008) and Blevins (2004), who argued that phonetic motivations for sound patterns only should be regard diachronic sound change.

However, for the low-level tone, the synchronic account makes the correct prediction that its occurrence is more associated with voiced onsets. This finding either shows that, to fully account for synchronic patterns, the diachronic phonetic account must be more precise about the pathway of sound change. Another interpretation to this finding is that synchronic phonology directly incorporates or reflect phonetic or perceptual motivation, as suggested in frameworks such as the Dispersion Theory (e.g., Flemming, 2004): One hypothesis might be a need to contrast these two tones: as these two tones occupy similar tonal range, mid-falling tone behaves like a high tone in this pair, at least in its initial tonal target, so that it contrasts better with the low-level tone. This hypothesis would also predict that the mid-falling tone's initial target should be reliably higher than that of the low-level tone, which is supported by acoustic measurements shown in Pan (2017).

As for the question on diachronic and synchronic explanations in phonological grammar, the mixed results make it difficult to assess whether the tone-onset association in Taiwanese is better explained by performance-based diachronic change or a synchronic grammar that affects the makeup of the lexicon. One direction to explore this further is to examine the distribution of onset and tone categories in different lexical strata within the Taiwanese lexicon (e.g., Tu, 2013, 2011): different lexical strata reflect pronunciations of certain syllable onsets at different stages of the Min language, which may shed light on the path of historical change on the onset-tone association.

To conclude, the present study has shown that there exists a certain connection between onset voicing and distribution of tones in the synchronic Taiwanese lexicon, although tonal categories behave differently as to whether such connection is better predicted by diachronic or synchronic tonal values. The quantitative measures of such connections make contribution to the understanding of Taiwanese lexicon, and the results have wider implications on the locus of phonetic motivation of sound patterns in languages and on the historical phonology of Chinese languages. Future directions of this project include looking at the relationship between onset and tone in other languages in the Min family, as well as testing whether speakers are aware of the lexical statistics about the distribution of tone and onset voicing across syllable types.

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