Mapping between Lexical Tones and Musical Notes in Thai Pop Songs

Chawadon Ketkaew
Department of Linguistics, Faculty of Arts, Chulalongkorn University, Phayathai Road, Pathumwan, Bangkok, 10330, Thailand
Chawadon.k@gmail.com

Pittayawat Pittayaporn
Department of Linguistics, Faculty of Arts, Chulalongkorn University, Phayathai Road, Pathumwan, Bangkok, 10330, Thailand
Pittayawat.P@chula.ac.th

Abstract

The aim of this paper is to examine the parallelism between tonal transitions and musical note transitions in Thai pop songs based on the data from 30 current pop songs. The results suggest that there is a statistically significant parallelism between tonal transitions and musical note transitions. Interestingly, the results show that both contour tones, RISING and FALLING, typically pattern with HIGH with respect to the mapping between tonal transitions and note transitions. Nevertheless, when two FALLING occur consecutively, the offset of the second one is used for mapping. Our results seem to find further support for decomposability of contour tones in Thai. Furthermore, they suggest that Thai pop music composition does not strive to maximize parallel transitions but prefer to avoid opposing transitions.

1. Introduction

Pitch is an important element in both language and music. In languages, pitch is used to convey different levels of meaning, e.g. lexical, sentential, attitudinal, emotional etc. In music, pitch serves the melodic structure, whether played on instruments or sung by voice, in order to express meaning to the listener. However, pitch in language and music differs with respect to how it is treated. While pitch in language is treated as a relative difference, pitch in music is treated as an absolute difference. Given their similarity and difference, it is important for our understanding of human cognition to examine the relationship between pitch in language and music. Of crucial relevance are languages that use patterns of relative pitch to convey lexical contrast. It is a puzzle how tonal languages relate their lexical tones to musical melody, which is made up of patterns of absolute pitch played on instruments or sung.

One pertinent question is how contour tones are treated in the mapping between tone and melody. To answer this question, the Thai language is a great case study because its five tones, shown in Table 1, have been studied quite extensively both in terms of acoustics, perception, as well as phonology. However, little research has been done on the mapping between lexical tones and music in Thai, especially with respect to the treatment of contour tones.

| Tone   | Example       | Tone value |
|--------|---------------|------------|
| MID    | khá: ‘to be stuck’ | [33]       |
| LOW    | khá: ‘galangal’ | [21]       |
| FALLING| khá: ‘value’   | [42]       |
| HIGH   | khá: ‘to trade’| [45]       |
| RISING | khá: ‘leg’     | [24]       |

Table 1: Thai lexical tones

Since in Thai songs syllables and musical notes are typically mapped to each other in a one to one relationship, an interesting question is how these complex tones are treated. In this paper, we examine the tone-melody mapping in current Thai pop songs. Our results indicate that, like other genres, Thai pop songs show a degree of parallelism between tonal transitions and musical note transitions. In addition, they show that both RISING and FALLING tones typically pattern with HIGH with respect to the mapping between tonal transitions and note transitions.
2. Literature review

Mapping between lexical tones and musical notes is one of the topics that have been widely studied in the past decade. While a few studies compare lexical tones to the absolute pitch of musical notes (Yung, 1983; Chao, 1956), some have investigated parallelism between tonal transitions and melodic transitions, i.e. mapping between the directions of adjacent note transitions and adjacent syllable transitions (Schellenberg, 2009; Wee, 2007; Ho, 2006; Baart, 2004; Wong and Diehl, 2002; Agawu, 1988). In our opinion, the latter method seems to be a more effective way to investigate the mapping between lexical tones and musical notes because it does not compare absolute pitch with relative pitch. Since pitch is treated as a relative difference in language but as an absolute difference in music, investigating mapping between individual tones and individual notes may miss crucial generalizations. It is thus more reasonable to examine pitch in both language and music in terms of relative pitch difference by comparing the directions of successive lexical tones and successive musical notes.

2.1 Study of tone-melody mapping in general

Most previous studies that investigated how lexical tones transitions and musical note transitions are mapped have revealed parallelism between tonal transitions and musical note transitions in languages. For example, Wong and Diehl’s (2002) results on Cantonese, based on four contemporary songs, show a very high degree of parallelism between musical and lexical melodies (91.81%).

The factors that have been reported to affect the degree of parallelism are their position within the melody. Wee (2007) suggested that the parallelism in Mandarin songs will be high in the most prominent beat in the Mandarin folk songs.

Shona, Schellenberg (2009) also examined the parallelism between speech and sung melody. Instead of using musical notes, he based his analysis on pitch tracks of the recorded songs. Despite the difference in methodology, this study still found a statistically significant number of parallel transitions.

However, cases that do not show parallelism between tonal transitions and musical note transitions do exist. For example, Agawu (1988) investigated northern Ewe songs and found that the pattern of tonal transitions did not match with sung melodies. In addition, Baart (2004) reported similar finding for Kalam Kohistani. Similarly, for mandarin pop songs, Ho (2006) suggested that there is a disagreement between tone and tune. Interestingly, in their study of Dagaare, a two-tone language without parallelism between tones and tunes, Bodomo and Mora (2000) suggested that the degree of parallelism relies on the number of tones in each language’s inventory. It predicts that in a language with a rich tonal inventory, the degree of parallelism will be high. However, studies on Kalam Kohistani (Baart, 2004) and Mandarin (Ho, 2006) disproved Bodoma and Mora’s hypothesis.

Another important issue is the treatment of contour tones. Since contour tones involve dynamic changes in pitch, it is puzzling how they are mapped with musical note transitions. Ho (2006) and Wong and Diehl’s (2002) studies on Cantonese pop songs suggested that the tonal endpoint of Cantonese contour tones are used as the relevant portion in mapping.

2.2 Study of tone-melody mapping in Thai

As for Thai, three important pioneering studies have revealed that Thai, like most tonal languages, is characterized by parallelism between the transition of lexical tones and the transitions between two adjacent musical notes. In other words, tonal transitions and note transitions between adjacent syllables in Thai songs typically agree in direction.

List (1961) examined the mapping between tonal transitions and musical notes in recitals and chants in Thai. The results show that the degree of parallelism between tones and sung pitch in recital reaches approximately 90 percent. In contrast, the correspondence between tones and musical notes is only approximately 60 percent in contemporary songs.

Similarly, the results of Saurman (1999) showed that the degree of parallelism between tones and tunes in classical and traditional songs is approximately 90 percent. For contemporary songs, which borrow elements of western music, the degree of mapping parallelism was between 60 to 70 percent. The parallelism was also low (42%) for western hymns translated into Thai.
Interestingly, the degree of mapping for the Thai national anthem was also only 32 percent. Not only do these studies reveal parallelism between tonal transition and sung pitch in Thai, it also shows that musical genres have an ineligible effect on the degree of parallelism. In addition, syllables that have been described as “surface toneless” (Bennett, 1995; Luksaneeyanawin, 1983; Bee, 1975) were excluded to avoid possible noises.

In summary, the results of many studies concerning Thai songs show that there is parallelism between tonal transitions and musical note transitions. However, most studies do not systematically examine how the contour tones are treated in Thai songs. Moreover, they are based on a limited number of songs. To reach a better understanding of the mapping between tonal and note transitions, we focused on the treatment of contour tones, based on data from a relatively large corpus of Thai pop music.

3. Methods

This study examined the parallelism between tonal transitions and musical note transitions in 30 popular Thai pop songs\(^1\). The melody of each song was transcribed using musical notation by the researcher. Moreover, music notations in this study were then double checked by a professional musician. The lyrics were transcribed using IPA symbols such that each syllable is aligned vertically to its corresponding musical notes as exemplified in Figure 1.

Note transitions between two adjacent syllables were manually extracted from the corpus, excluding cases of one-to-many and many-to-one mapping of syllables and musical notes. To control the boundary effects, transitions across the melodic phrase boundaries were also excluded. In

\(^1\) This data is part of a larger corpus in progress. At the end of its first phase, the corpus will consist of 100 songs covering a considerable variety in terms of composers, keys of songs and genders.
4. Treatment of contour tones

To examine how tonal transitions and note transitions are mapped, we carried out a statistical analysis to test whether the tone pairs are preferably mapped with ascending, descending, or level note transitions. The Friedman test provides a means to test whether several groups differ significantly and it is used for data that does not show normal distribution. However, the Friedman test only tells us whether there are statistically significant differences among groups. It cannot identify which pair is significantly different. Therefore, the Wilcoxon test is required to examine which pairs differ from each other significantly. In this study, the 25 tone pairs and the three directions of note transitions were the independent variables and the dependent variables respectively.

4.1 Ascending transitions

Tone pairs that occur with ascending note transitions more often than other types at a statistically significant level were classified as having ascending tonal transition.

Among the 25 pairs of tones in adjacent syllables, five, shown in Table 3, belong to this type of transition. All the tone pairs that are preferably mapped with ascending note transitions are ones whose second member is higher in pitch than the first.

![Table 3: Ascending transition](image)

As expected, the results in Table 3 show that ascending note transitions were mapped with tone pairs with a higher second tone. In particular, cases of MID → HIGH were mapped with ascending transition at a statistically significant level (p<0.001). Similarly, tonal transitions of the types LOW → MID and LOW → HIGH were also mapped with ascending note transitions at a statistically significant level (p<0.05). Most importantly, both MID → RISING and LOW → RISING were mapped with ascending note transitions at a statistically significant level (p<0.01). This indicates that RISING behaves like HIGH with respect to tone-melody mapping. In other words, the RISING is treated as if it was HIGH.

4.2 Descending transitions

The tone pairs that were mapped with descending note transitions more often than other types at a statistically significant level were classified as having descending tonal transitions.

![Table 4: Descending transition](image)

As shown in Table 4, tone pairs in which the second tone is lower than the first one were typically matched with descending note transitions. To illustrate, cases of MID → LOW were mapped with descending note transitions at a statistically significant level (p<0.01). Similarly, HIGH → MID and HIGH → LOW were also mapped with descending note transitions at a statistically significant level (p<0.01). As expected, RISING → MID and RISING → LOW were also mapped with descending note transitions at a statistically significant level (p<0.05), providing further support for grouping RISING with HIGH. In addition, FALLING → MID and FALLING → LOW were also mapped with descending note transitions at a statistically significant level (p<0.05). This indicates the fact that FALLING → FALLING were mapped descending tonal transitions (p<0.05). If FALLING is always treated as if it was HIGH, we would expect two consecutive FALLINGS to be matched with level musical transitions. An explanation for this surprising mapping will be discussed later (see section 6).
4.3 Level transitions

Tone pairs that were frequently mapped with level note transitions than other types at a statistically significant level were classified as having a level tonal transition.

| Tone pairs | Musical note transition |  
|------------|-------------------------|
|            | Ascending | Descending | Level  |
| LOW→LOW    | 17(23%)   | 17(23%)    | 40(54%) |
| HIGH→HIGH  | 13(15.9%) | 21(25.6%)  | 48(58.5%) |

Table 5: Level transition

For level musical note transitions, only two tone pairs with identical first and second member occurred with this type of transition at a statistically significant level. From Table 5, only LOW → LOW and HIGH → HIGH were mapped with level musical notes transitions at a statistically significant level (p<0.05). Interestingly, MID → MID does not follow the same pattern.

In summary, the results suggest that both RISING and FALLING are treated as if they were HIGH. In the case of RISING, its offset is used as a reference for tonal mapping. For FALLING, the result reveals, in contrast, that its onset is the important element in the mapping. Intriguingly, the pair FALLING → FALLING is also considered to have a descending tonal transition rather than a level transition.

5. Result of Parallelism

Based on the results in 4, tonal transitions were grouped into 3 categories according to their directions, as summarized in Table 6. Note that the RISING and FALLING are treated as if they were HIGH. One exception is FALLING → FALLING, which was classified as a descending rather than a level transition.

| Ascending tonal transition | Descending tonal transition | Level tonal transition |
|----------------------------|-----------------------------|------------------------|
| MID→HIGH                   | MID→LOW                     | MID→MID                |
| MID→RISING                 | FALLING→LOW                 | LOW→LOW                |
| MID→FALLING                | FALLING→LOW                 | FALLING→HIGH           |
| LOW→MID                    | FALLING→FALLING             | HIGH→FALLING           |
| LOW→FALLING                | HIGH→MID                    | HIGH→HIGH              |
| LOW→HIGH                   | HIGH→LOW                    | HIGH→RISING            |
| LOW→RISING                 | RISING→LOW                  | RISING→FALLING          |
|                            | RISING→LOW                  | RISING→HIGH            |

Table 6: Tonal transition categories

After assigning the tonal transitions to the tone pairs, we coded the mapping between the tonal transitions and musical note transitions in terms of parallel, opposing and non-opposing. Tonal target transition which agrees with musical transition in terms of directions of pitch change was coded as parallel. We coded it as opposing if the tone transition and note transition went in opposite directions. Tonal and note transition that did not agree in direction but did not go in opposite directions, was coded as non-opposing.

This analysis used the Friedman and Wilcoxon test to examine whether certain types of tonal transitions are mapped with certain types of musical note transitions. Table 7 shows the percentage of parallelism between tonal transitions and note transitions.

| Tonal transition | Melodic transition |  
|------------------|-------------------|
| Ascending        | Descending        | Level  |
| 1091(22.57%)     | 317 (6.43%)       | 230 (4.63%) |
| (parallel)       | (opposing)        | (non-opposing) |
| 415 (8.48%)      | 1039 (21.49%)     | 275 (5.57%) |
| (opposing)       | (parallel)        | (non-opposing) |
| 426 (8.71%)      | 483(9.9%)         | 594 (12.22%) |
| (non-opposing)   | (opposing)        | (parallel) |

Table 7: Parallelism between tonal transitions and melodic transitions

From table 7, for all 30 Thai pop songs, the total sum of mapping between tones and musical
notes had 4798 transitions. Parallel mapping between tonal transitions and musical transition occurred at 55.3 percent. This was more often than opposing and non-opposing transitions at a statistically significant level (p<0.001). Also, 732 cases of the mapping between tonal and musical transitions were opposing (732/4798, 15.25%). Interestingly, the number of non-opposing transitions (1414/4798, 29.47%) occurred more often than opposing transitions at a statistically significant level (p<0.001). This seems to indicate that non-opposing transitions are acceptable in Thai pop music.

In summary, our results show that parallel transitions occur more frequently than the mapping of opposing transitions. Adjacent tones in which the second tone has a higher pitch than the previous one was mapped with an ascending melodic transition. Likewise, successive tones in which the second note is lower than the previous one were mapped with descending melodic transitions. However, tones of the same height which occurred adjacently tended to slightly map with level transitions.

6. Discussion

From our results, three issues deserve special attention: decomposability of contour tones, non-opposing mapping, and some factors that should be controlled for future study.

Firstly, this study offers further evidence in support of decomposability of Thai contour tones. In the case of RISING, our study found that the tonal offset has to be referred to in the tone-melody mapping. This suggests that RISING is composed of L followed by H rather than being an atomic unit. In the case of FALLING, our study showed that the tonal onset of FALLING in Thai normally has to be referred, confirming Ho’s observation that the onset is the more important element or headship of FALLING in tone-melody mapping. Nevertheless, from our results, not only is FALLING’s tonal onset important, but also its tonal offset is relevant for the mapping. To illustrate, when two FALLING occur consecutively, the offset of the second one is used for mapping. This fact also suggests that FALLING is composed of level tones (H followed by L) rather than being a unitary unit. From the phonological perspective, many phonologists, e.g. Gandour (1974a), Yip (1982) and Morén and Zsiga (2006), argue convincingly that contour tones in Thai are in fact made up of sequences of H and L. In other words, FALLING and RISING can be represented as [HL] and [LH] respectively. Therefore, our results lend further support for decomposability of contour tones in Thai.

Secondly, non-opposing transitions are acceptable in Thai pop music. As seen from a previous section, non-opposing transitions occur more often than opposing transitions at statistically significant levels. More specifically, when tone pairs with identical first and second members occur successively, although they tend to map with musical level transition, the percentage of mapping with musical ascending and descending transitions is close to that of level transitions. In other words, Thai pop music composition does not strive to maximize parallel transitions but tries to avoid opposing ones. The results should be further tested by perception studies in the future.

Finally, some additional factors should be studied in order to obtain a clearer picture of parallelism. To elaborate, the greater degree of parallelism might occur if we control for such factors as the note value and word stress. For note value, parallel transition tended to map with the note which contained the most prominent beat in the phrase of the songs. Furthermore, we observed most of FALLING was mapped with stressed grammatical words. For example, words like /mâj/ ‘not’, /kɔ/ ‘also’, /tʰiː /’REL’, /yín/ and /tɔŋ/ ‘must’ occurred frequently in our data and created opposing transitions. Excluding grammatical words and unstressed words might yield a lower percentage of opposing transitions. To conclude, in future studies, factors like stress, note value and grammatical word status should be also controlled for clearer results.

7. Conclusion

Based on data from a larger corpus than earlier studies, our results suggest that in Thai pop songs, like other genres, there is a statistically significant parallelism between tonal transitions and musical note transitions. They also agree with the findings by Ho (2006), who assumes that one of the two components of contour tones is taken as dominant and used as a reference in tone-melody mapping. To illustrate, both RISING and FALLING tones pattern with HIGH. Moreover, when two FALLING occur consecutively, the offset of the second FALLING is used for mapping. The results also
provide further evidence for the decomposability of contour tones in Thai. Furthermore, the results also suggest a new way of looking at parallelism between tone transitions and musical note transitions. In particular, they suggest that the composition of Thai pop songs places more importance on avoidance of opposing transitions than achieving parallel transitions.

Acknowledgments

This research is a part of the first author’s doctoral dissertation. It is supported by the Ratchadaphiseksomphat Endowment Fund of Chulalongkorn University (RES560530179-HS). Moreover, we wish to express sincere gratitude to Songphan Choemprayong for his advice on data and statistics. Many thanks are also extended to Yanin Sawanakunanon, Karntida Kerdpol, Junyawan Suwannarat, Teeranoot Siriwittayakorn, Thanakas Sirikanerat and Ponlawat Laimanoo for their help with statistics and valuable comments.

References

Agawu, V.Kofi. (1988). Tone and Tune: The Evidence for Northern Ewe Music. *Africa: Journal of the International African Institute*, 58(2), 127-146.

Baart, Joan L.G. (2004). Tone and song in Kalam Kohistani (pakistan). In *On Speech and Language: Studies for Sieb G. Nooteboom*, Utrecht: Nethelands Graduate School of Linguistics, 5-16.

Bee, Peter. (1975). Restricted phonology in certain Thai linker-syllabables. In J.G. Harris and J.R. Chamberlain (Ed.), *Studies in Tai Linguistics in Honor of William J. Gedney*, 17-32. Central Institute of English Language.

Bennett, Fraser J. (1994). Iambicity in Thai. *Studies in the Linguistic Sciences*, 24, 39-57.

Bodomo, Adams, & Mora, Manolete. (2000). Language and Music in the Dagaare and Twi Folktakes of West Africa. *CRCG Project notes, University of Hong Kong*.

Chan, Marjorie. (1987). Tone and melody in Cantonese. In *Proceedings of the Thirteenth Annual Meeting of the Berkeley Linguistics Society*, 26-37.

Chao, Yuen Ren. (1956). Tone, intonation, singsong, chanting, recitative, tonal composition and tonal composition in Chinese. In M. Halle, H.G. Lunt, H. McLean and C.H. Van Schooneveld (Ed.), *For Roman Jacobson: Essays on the occasion of his sixtieth birthday, 11th October 1956* (pp. 52-59). The Hague: Monton & Co.

Gandour, Jackson. (1974). Consonant types and tone in Siamese. *Journal of Phonetics*, 2, 337-350.

Ho, Wing See Vinnie. (2006, August 22-26). The tone-melody interface of popular songs written in tone languages. Paper presented at the 9th International Conference on Music Perception and Cognition, Alma Master Studiorum University of Bologna.

List, George. (1961). Speech melody and song melody in Central Thailand. *Ethnomusicology*, 5(1), 16-32.

Luksaneeyawin, Sudaporn. (1983). *Intonation in Thai*. University of Edinburgh, Unpublished.

Morén, Bruce, and Elizabeth Zsiga. 2006. The lexical and post-lexical phonology of Thai tones. *Natural Language and Linguistic Theory* 24:113-78.

Saurman, Mary Elisabeth. (1999). The agreement of *List, George. (1961). Speech melody and song melody in Central Thailand. Ethnomusicology, 5(1), 16–32. Luksaneeyawin, Sudaporn. (1983). *Intonation in Thai*. University of Edinburgh, Unpublished. . Morén, Bruce, and Elizabeth Zsiga. 2006. The lexical and post-lexical phonology of Thai tones. *Natural Language and Linguistic Theory* 24:113-78.

Schellenberg, Murray. (2009). *Singing in a Tone Language: Shona*. Paper presented at the Selected Proceedings of the 39th Annual Conference on African Linguistics.

Wong, Patrick C. M, & Diehl, Randy L. (2002). How can the lyrics of a song in a tone language be understood? *Psychology of Music*, 30(2), 202-209.

Yip, Mora. (1982). Against a Segmental Analysis of Tone and Tune: The Evidence of contour tones in Thai.

Benjawan Siew, Thew, & Phai, Yiew, 2010. Unraveling the Relation between Musical Melody and Mandarin Tones. *Proceedings of the 39th Annual Conference on Music Perception and Cognition*, 19-32.

Yung, Bell. (1989). *Cantonese opera: performance as creative process*. Cambridge University Press.

Appendix A: List of 30 songs

1. เธอถึง/ thè yìng/  nái thà/ 
2. หู/กูริบิ้น/jù ták jângdâi/ 
3. ใจกลางความรู้สึก/câ̄i klâːŋ khwâːmrúːsúk dîː/ dîː/ 
4. ใครจะรู้/khraj nijəːʔ/m/ 
5. ขอโทษ/phêːː câ/ 
6. ผู้วิจารณ์เพื่อนเพื่อน/phû puaj khwâːmcâm sîːm/ 
7. ขอให้คุณรัก/mâːk dâjìːn wáː râkkâːn/ 
8. รักเป็นจริง/rák pâːtihâːn/ 
9. ขอโทษที่ใจก็ไม่ยา/CA hâːj chàm thâm jângdâi/ 
10. รักถึงขอรักที่ใจ/rák thèː jùːnía kâːnwâːlâː/ 
11. โทษของคนที่คุณไม่รัก/klâːŋ kâːn̩ kâː niŋ kâːn̩ / 
12. กลับมาในฝันอีกครั้ง/klâːp mâː pêːn mîːn dâːm dâjìːmâː/ 
13. หันความ dez.kom ฉันเพราะ/nîŋ khwâːmē ngâː bôːn dâːw khraj̩?

References

Agawu, V.Kofi. (1988). Tone and Tune: The Evidence for Northern Ewe Music. *Africa: Journal of the International African Institute*, 58(2), 127-146.

Baart, Joan L.G. (2004). Tone and song in Kalam Kohistani (pakistan). In *On Speech and Language: Studies for Sieb G. Nooteboom*, Utrecht: Nethelands Graduate School of Linguistics, 5-16.

Bee, Peter. (1975). Restricted phonology in certain Thai linker-syllabables. In J.G. Harris and J.R. Chamberlain (Ed.), *Studies in Tai Linguistics in Honor of William J. Gedney*, 17-32. Central Institute of English Language.

Bennett, Fraser J. (1994). Iambicity in Thai. *Studies in the Linguistic Sciences*, 24, 39-57.

Bodomo, Adams, & Mora, Manolete. (2000). Language and Music in the Dagaare and Twi Folktakes of West Africa. *CRCG Project notes, University of Hong Kong*.

Chan, Marjorie. (1987). Tone and melody in Cantonese. In *Proceedings of the Thirteenth Annual Meeting of the Berkeley Linguistics Society*, 26-37.

Chao, Yuen Ren. (1956). Tone, intonation, singsong, chanting, recitative, tonal composition and tonal composition in Chinese. In M. Halle, H.G. Lunt, H. McLean and C.H. Van Schooneveld (Ed.), *For Roman Jacobson: Essays on the occasion of his sixtieth birthday, 11th October 1956* (pp. 52-59). The Hague: Monton & Co.

Gandour, Jackson. (1974). Consonant types and tone in Siamese. *Journal of Phonetics*, 2, 337-350.

Ho, Wing See Vinnie. (2006, August 22-26). The tone-melody interface of popular songs written in tone languages Paper presented at the 9th International Conference on Music Perception and Cognition, Alma Master Studiorum University of Bologna.

List, George. (1961). Speech melody and song melody in Central Thailand. *Ethnomusicology*, 5(1), 16–32. Luksaneeyawin, Sudaporn. (1983). *Intonation in Thai*. University of Edinburgh, Unpublished. . Morén, Bruce, and Elizabeth Zsiga. 2006. The lexical and post-lexical phonology of Thai tones. *Natural Language and Linguistic Theory* 24:113-78.

Schellenberg, Murray. (2009). *Singing in a Tone Language: Shona*. Paper presented at the Selected Proceedings of the 39th Annual Conference on African Linguistics.

Wong, Patrick C. M, & Diehl, Randy L. (2002). How can the lyrics of a song in a tone language be understood? *Psychology of Music*, 30(2), 202-209.

Yip, Mora. (1982). Against a Segmental Analysis of Tone and Tune: The Evidence of contour tones in Thai.

Benjawan Siew, Thew, & Phai, Yiew, 2010. Unraveling the Relation between Musical Melody and Mandarin Tones. *Proceedings of the 39th Annual Conference on Music Perception and Cognition*, 19-32.

Yung, Bell. (1989). *Cantonese opera: performance as creative process*. Cambridge University Press.

Appendix A: List of 30 songs

1. เธอถึง/ thè yìng/  nái thà/ 
2. หู/กูริบิ้น/jù ták jângdâi/ 
3. ใจกลางความรู้สึก/câ̄i klâːŋ khwâːmrúːsúk dîː/ dîː/ 
4. ใครจะรู้/khraj nijəːʔ/m/ 
5. ขอโทษ/phêːː câ/ 
6. ผู้วิจารณ์เพื่อนเพื่อน/phû puaj khwâːmcâm sîːm/ 
7. ขอให้คุณรัก/mâːk dâjìːn wáː râkkâːn/ 
8. รักเป็นจริง/rák pâːtihâːn/ 
9. ขอโทษที่ใจก็ไม่ยา/CA hâːj chàm thâm jângdâi/ 
10. รักถึงขอรักที่ใจ/rák thèː jùːnía kâːnwâːlâː/ 
11. โทษของคนที่คุณไม่รัก/klâːŋ kâːn̩ kâː niŋ kâːn̩ / 
12. กลับมาในฝันอีกครั้ง/klâːp mâː pêːn mîːn dâːm dâjìːmâː/ 
13. หันความ dez.kom ฉันเพราะ/nîŋ khwâːmē ngâː bôːn dâːw khraj̩?
14. ก่อนหน้านั้น/ค่อนหน้านั้น/ก่อนก่อน
15. ท่านตนเอง/ท่านตนเอง
16. ทานทาน/ทานทาน
17. ความเห็น/ความเห็น
18. Unlovable
19. คนธรรมดา/คนธรรมดา
20. อีกนานไหม/อีกนานไหม
21. ยิ่งยิ่งยิ่ง/ยิ่งยิ่งยิ่ง
22. คณฑีสินส้ม/คณฑีสินส้ม
23. น้อย/น้อย
24. ไม่ไหวไม่ไหว/ไม่ไหวไม่ไหว
25. ฉันจะรักเธอ/ฉันจะรักเธอ
26. เธอจะรักฉันรักฉันไม่รู้/เธอจะรักฉันรักฉันไม่รู้
27. หูทวนลม/หูทวนลม
28. ผ่านมาดีใจ/ผ่านมาดีใจ
Table 8: Tone pairs mapped with ascending note transitions

| Tone Pair         | Friedman χ² Test (All transition types compared) |
|-------------------|-----------------------------------------------|
| MID→LOW           | 14.000                                       |
| FALLING→LOW       | 20.484                                       |
| FALLING→MID       | 11.707                                       |
| FALLING→FALLING   | 7.635                                        |
| HIGH→MID          | 10.927                                       |
| RISING→MID        | 17.175                                       |
| LOW→MID           | 36.493                                       |

*Note: N=30, *p<0.05, **p<0.01; Based on positive ranks*

Table 9: Tone pairs mapped with descending note transitions

| Tone Pair         | Friedman χ² Test (All transition types compared) |
|-------------------|-----------------------------------------------|
| MID→LOW           | 33.163                                       |
| FALLING→LOW       | 10.085                                       |
| FALLING→MID       | 24.721                                       |
| FALLING→FALLING   | 12.064                                       |
| LOW→MID           | 42.466                                       |
| FALLING→LOW       | 27.000                                       |
| FALLING→MID       | 18.406                                       |
| FALLING→FALLING   | 37.163                                       |

*Note: N=30, *p<0.05, **p<0.01; Based on positive ranks*
### Table 10: Mapping between Directions of Tonal and Musical Transitions

**Notes:** N=30, *p<0.05, **p<0.01; Based on negative ranks

| Tone Pairs | Wilcoxon Test (Parallel and Opposing Compared) | Wilcoxon Test (Parallel and Non-Opposing Compared) | Wilcoxon Test (Opposing and Non-Opposing Compared) | Friedman χ² Test (All Type of Relations Compared) |
|------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------|-----------------------------------------------|
| MID→MID   | Asymp. Sig (compared) Z (2-tailed)             | Asymp. Sig (non-compared) Z (2-tailed)            | Asymp. Sig (opposing & non-opposing compared) Z  | χ² (2-tailed)                                |
| LOW→LOW   | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |
| FALLING→HIGH | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| FALLING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→FALLING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→HIGH | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| FALLING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| RISING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| LOW→LOW | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |
| MID→MID   | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |

### Appendix C: Friedman and Wilcoxon Test

Note: N=30, *p<0.05, **p<0.01; Based on positive ranks

### Table 11: Mapping between Directions of Tonal and Musical Transitions

**Notes:** N=30, *p<0.05; **p<0.01

| Tone Pairs | Wilcoxon Test (Parallel and Opposing Compared) | Wilcoxon Test (Parallel and Non-Opposing Compared) | Wilcoxon Test (Opposing and Non-Opposing Compared) | Friedman χ² Test (All Type of Relations Compared) |
|------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------|-----------------------------------------------|
| MID→MID   | Asymp. Sig (compared) Z (2-tailed)             | Asymp. Sig (non-compared) Z (2-tailed)            | Asymp. Sig (opposing & non-opposing compared) Z  | χ² (2-tailed)                                |
| LOW→LOW   | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |
| FALLING→HIGH | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| FALLING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→FALLING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→HIGH | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| FALLING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| RISING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| LOW→LOW | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |
| MID→MID   | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |

### Table 12: Tone Pairs Mapped with Level Note Transitions

Note: N=30, *p<0.05; **p<0.01

| Tone Pairs | Wilcoxon Test (Parallel and Opposing Compared) | Wilcoxon Test (Parallel and Non-Opposing Compared) | Wilcoxon Test (Opposing and Non-Opposing Compared) | Friedman χ² Test (All Type of Relations Compared) |
|------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------|-----------------------------------------------|
| MID→MID   | Asymp. Sig (compared) Z (2-tailed)             | Asymp. Sig (non-compared) Z (2-tailed)            | Asymp. Sig (opposing & non-opposing compared) Z  | χ² (2-tailed)                                |
| LOW→LOW   | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |
| FALLING→HIGH | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| FALLING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→FALLING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→HIGH | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| HIGH→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| FALLING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| RISING→RISING | 4.283                                        | 4.283                                           | 4.283                                            | 55.882                                       |
| LOW→LOW | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |
| MID→MID   | **0.000**                                     | **0.000**                                        | **0.000**                                        | 55.882                                       |