Mapping between Lexical Tones and Musical Notes in Thai Pop Songs

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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	khā: 'to be stuck'	[33]
LOW	khà: 'galangal'	[21]
FALLING	khâ: 'value'	[42]
HIGH	khá: 'to trade'	[45]
RISING	khǎ: 'leg'	[24]

Table1: 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.

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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 between 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.

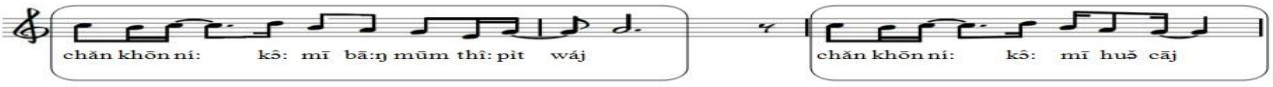


Figure 1: the sample of transcribed song using musical notation

In addition, Ho (2006) applied the idea of using the tonal endpoint in one Thai pop song and found that the tonal onset of FALLING may be the relevant part for mapping. More importantly, her study showed that the degree of parallelism is approximately 80 percent. In her observations, the mismatches are generally caused by FALLING.

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 addition, syllables that have been described as "surface toneless" (Bennett, 1995; Luksaneeyanawin, 1983; Bee, 1975) were excluded to avoid possible noises.

By identifying such toneless syllables with Luksaneeyawin's "linking syllables", we were able to exclude all unstressed CV syllables containing /a/. For example, words like /rátthàbāːn/ "government" and /thɔ̄ːrámāːn/ "suffer" are typically realized as [ˌrátthəˈbāːn] and [ˌthɔ̄ːrəˈmāːn] respectively. In these cases, /-tha-/ and /-ra-/ were not included in the analysis.

After extracting the eligible adjacent syllables, we then classified the directions of the musical note transitions into three major groups: ascending, level and descending. If the second note was higher in pitch than the first one, e.g. from note C to note D, we assigned the musical transition to the ascending category. When second note was lower than the first one, e.g. from note E to note D, we counted it as having a descending transition. Lastly, if the adjacent notes were identical in pitch, e.g. from note F to note F, we classified its note transition as a level transition. Crucially, we did not set an *a priori* assumption on how the contour tones were decomposed into sequences of H's and L's. Instead, we used the five lexical tones as primes in the analysis. Below are the 25 pairs of adjacent tones used to compare with directions of note transitions.

MID→MID	FALLING→HIGH
MID→LOW	FALLING→RISING
MID→FALLING	HIGH→MID
MID→HIGH	HIGH→LOW
MID→RISING	HIGH→FALLING
LOW→MID	HIGH→HIGH
LOW→LOW	HIGH→RISING
LOW→FALLING	RISING→MID
LOW→HIGH	RISING→LOW
LOW→RISING	RISING→FALLING
FALLING→MID	RISING→HIGH
FALLING→LOW	RISING→RISING
FALLING→FALLING	

Table2: 25 Tone pairs

[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.

Tone pairs	Musical note transition		
	Ascending	Descending	Level
MID→HIGH	136(68.7%)	37(18.7%)	25(12.2%)
MID→RISING	111(71.6%)	31(20%)	13(8.4%)
LOW→MID	186(64.8%)	38(13.2%)	63(22%)
LOW→RISING	45(81.8%)	3(5.5%)	7(12.7%)
LOW→HIGH	63(77.8%)	14(17.3%)	4(4.9%)

Table 3: Ascending transition

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.

Tone pairs	Musical note transition		
	Ascending	Descending	Level
MID→LOW	52(15%)	229(66.4%)	64(18.6%)
FALLING→MID	130(28.8%)	244(54.1%)	77(17.1%)
FALLING→LOW	14(11.9%)	67(56.8%)	37(31.3%)
FALLING→FALLING	31(21.7%)	70(48.9%)	42(29.4%)
HIGH→MID	17(7.7%)	183(82.4%)	22(10%)
HIGH→LOW	4(6.8%)	47(79.7%)	8(13.5%)
RISING→MID	27(13.2%)	164(80%)	14(6.8%)
RISING→LOW	7(12.1%)	46(79.3%)	5(8.6%)

Table 4: Descending transition

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 ($p<0.01$), 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 ($p<0.05$), suggesting that FALLING also patterns with HIGH. Most interestingly is 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%)

Table5: 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.

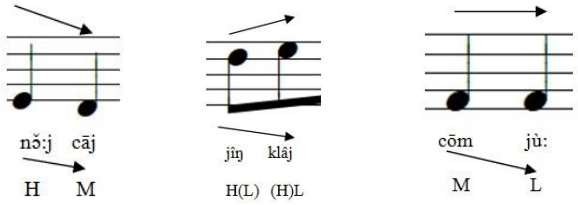
5. Result of Parallelism

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→RISING MID→FALLING LOW→MID LOW→FALLING LOW→HIGH LOW→RISING	MID→LOW FALLING→LOW FALLING→MID FALLING→FALLING HIGH→MID HIGH→LOW RISING→LOW RISING→MID	MID→MID LOW→LOW FALLING→HIGH FALLING→RISING HIGH→FALLING HIGH→HIGH HIGH→RISING RISING→FALLING RISING→RISING RISING→HIGH

Table6: 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.



Parallel Opposing Non-opposing

Figure 2: Example of parallel, opposing and non-opposing transitions

This analysis used the Freidman and Wilcoxon test to examine whether certain types of tonal transitions are mapped with certain types of musical note transitions. Table7 shows the percentage of parallelism between tonal transitions and note transitions.

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

Sum of diagonal cell 55.3%

Table7: 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', /kɔ̂/ 'also', /thî: /'REL', /yîŋ/ and /tɔ̂ŋ/'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 FALLINGs 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 Ratchadaphiseksomphot 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, Thanasak Sirikanerat and Ponlawat Laimanoo for their help with statistics and valuable comments.

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Appendix A: List of 30 songs

1. เธอยัง /thə: jāŋ/
2. หยุดรักยังไง/jùt rák jāŋŋāj/
3. ใจกลางความรู้สึกดีดี/cāj klā:ŋ khwā:mrú:sùk dī: dī:/
4. ใครนิยาม/khrāj nijā:m/
5. แพ้ใจ/phé: cāj/
6. ผู้ป่วยความจำเสื่อม/phû puèj khwā:mcām sìəm/
7. อยากได้ยินว่ารักกัน/jà:k dâjjīn wâ: rákkān/
8. รักปาฏิหาริย์/rák pā:tihă:n/
9. จะให้ฉันทำยังไง/ca hâj chăn thām jāŋŋāj/
10. รักแท้อยู่เหนือกาลเวลา /rák thé: jù:nɨ̌ə kā:nwē:lā:/
11. ไกลแค่ไหนคือใกล้/klāj kê:năj khī: klâj/
12. กลับมาเป็นเหมือนเดิม /klàp mā: pēn míən də̄:m dâjmăj/
13. หนึ่งความเหงาบนดาวเคราะห์ /nɨ̀ŋ khwā:mŋăw bōn dā:wkhrɔ́ʔ/

14. ก้อนหินก้อนนั้น/kɔ̂:nhǐn kɔ̂:n nán/
15. คนธรรมดา/khōn thāmmadā:/
16. จำทำไม/cām thāmmāj/
17. หวามเย็น/wă:njēn/
18. Unlovable
19. ไม่ใกล้ไม่ไกล/mâj klâj mâj klāj/
20. อีกนานไหม/ʔì:k nā:n măj/
21. ยิ่งรู้จักยิ่งรักเธอ/jîŋ rú:càk jîŋ rák thə:/
22. คนแพ้ที่ไม่มีน้ำตา/khōn phɛ́:thî: mâ:j mī: námtā:/
23. น้อย/nɔ́:j/
24. ไม่บอกเธอ/mâj bɔ̀:k thə:/
25. ฉันก็รักของฉัน/chăn kɔ rák khɔ̌:ŋ chăn/
26. เรื่องจริงยิ่งกว่านิยาย/rɨ̂əŋ cīŋ jîŋ kwà: nijā:j/
27. เธอจะรักฉันรึเปล่าไม่รู้
    /thə̄: ca rák chăn rɨpàw mâj rú:/
28. เรือเล็กควรออกจากฝั่ง/rɨ̄ə lék khūən ʔɔ̀:k cà:k fàŋ/
29. หูทวนลม/hŭ: thūənlōm/
30. ผ่านมาแค่ให้จำ/phà:n mā: khɛ̂: hâj cām/

Appendix B: Friedman and Wilcoxon test: Tone pairs that map with musical transition

	Wilcoxon test (Ascending and Descending compared)		Wilcoxon test (Ascending and Level compared)		Wilcoxon test (Descending and Level compared)		Friedman χ^2 test (All transition types compared)	
	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	χ^2	Asymp. Sig
MID→HIGH	-3.369	0.000**	-3.656	0.000**	-0.806	0.420	14.000	.001**
MID→RISING	-3.515	0.000**	-4.114	0.000**	-2.150	0.032*	20.484	.000**
MID→FALLING	-1.237	0.216	-2.680	0.007**	-3.447	0.001**	11.707	.003*
LOW→MID	-3.779	0.000**	-3.081	0.002**	-0.965	0.335	7.635	.022
LOW→FALLING	-3.408	0.001**	-1.883	0.060	-0.919	0.358	10.927	.004*
LOW→HIGH	-3.301	0.001**	-3.792	0.000**	-1.977	0.048*	17.175	.000**
LOW→RISING	-3.972	0.000**	-4.165	0.000**	-1.100	0.271	36.493	.000**

Table8: Tone pairs mapped with ascending note transitions
Note: N=30, *p<0.05; **p<0.01; Based on positive ranks

	Wilcoxon test (Descending and Ascending compared)		Wilcoxon test (Descending and Level compared)		Wilcoxon test (Ascending and Level compared)		Friedman χ^2 test (All transition type compared)	
	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	χ^2	Asymp. Sig
MID→LOW	-4.550	0.000**	-4.524	0.000**	-0.567	0.571	37.646	.000**
FALLING→LOW	-3.513	0.000**	-2.047	0.041*	-2.674	0.007**	15.085	.001*
FALLING→MID	-3.261	0.000**	-4.056	0.000**	-1.702	0.089	24.721	.000**
FALLING→FALLING	-3.204	0.001**	-2.016	0.044*	-0.747	0.455	12.064	.002*
HIGH→MID	-4.585	0.000**	-4.514	0.000**	-0.216	0.829	42.466	.000**
HIGH→LOW	-3.665	0.000**	-3.271	0.001**	-0.702	0.483	27.000	.000**
RISING→LOW	-3.035	0.002**	-3.471	0.001**	-0.612	0.541	18.406	.000**
RISING→MID	-4.214	0.000**	-4.551	0.000**	-1.646	0.100	37.163	.000**

Table9: Tone pairs mapped with descending note transitions
Notes: N=30, *p<0.05; **p<0.01; Based on positive ranks

	Wilcoxon test (Level and Ascending compared)		Wilcoxon test (Level and Descending compared)		Wilcoxon test (Ascending and Descending compared)		Friedman χ^2 test (All transitions types compared)	
	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	χ^2	Asymp. Sig
MID→MID	-2.923	0.003**	-0.751	0.453	-3.309	0.001*	12.463	0.002*
LOW→LOW	-2.597	0.009**	-2.951	0.003**	-2.957	0.009*	7.446	0.024*
FALLING→HIGH	-		-		-		2.742	0.254
FALLING→RISING	-0.018	0.986	-2.999	0.003**	-2.999	0.003**	7.600	0.022*
HIGH→FALLING	-2.298	0.022*	-1.500	0.133	-4.115	0.000**	26.687	0.000**
HIGH→HIGH	-2.691	0.007**	-2.041	0.041*	-0.423	0.673	6.416	0.040*
HIGH→RISING	-		-		-		0.747	0.688
RISING→FALLING	-2.737	0.006**	-1.919	0.055	-3.244	0.001*	12.341	0.002*
RISING→RISING	-		-		-		4.056	0.132
RISING→HIGH	-		-		-		0.700	0.705

Table10: Tone pairs mapped with level note transitions
Notes: N=30, *p<0.05; **p<0.01; Based on positive ranks

Appendix C: Friedman and Wilcoxon test:

	Wilcoxon test (Parallel and opposing compared)		Wilcoxon test (Parallel and non-opposing compared)		Wilcoxon test (Opposing and non-opposing compared)		Friedman χ^2 test (All type of relation compared)	
	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	Z	Asymp. Sig (2 – tailed)	χ^2	Asymp. Sig
	-4.783	0.000**	-4.783	0.000**	-4.283a	0.000**	55.882	0.000**

Table11: Mapping between directions of tonal and musical transitions
Note N=30, *p<0.05; **p<0.01; Based on negative ranks