An Optimality-theoretic Analysis of the Tone-melody mapping in Cantonese Popular Songs

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Abstract
This paper provides a preliminary analysis of some mapping phenomena at the tone-melody interface in Cantonese popular songs. Pitch is one of the common acoustic properties shared by language and music. In tone languages in particular, pitch variations are contrastive and therefore play an important role in differentiating word meanings. The question that arises is whether the lexical tones correspond to the melody of a song written in these languages, and if so, to what extent and how tone and tune match. This study investigates a sample of popular songs written in Cantonese, a language with a relatively complex tonal inventory. In all the Cantonese songs collected and analyzed, it is observed that tone and tune correlate closely, and the patterns of correlation are found to be quite systematic. It is suggested that these regular mapping characteristics can be accounted for by constraint interaction from the optimality-theoretic perspective. Optimality Theory, being one of the current central linguistic theories in the areas of phonology and syntax, is adopted as the theoretical framework in this study, and is extended to address tonal issues at the interface of language and music.

1. Introduction
Despite the close resemblance of language and music in terms of their acoustic nature, little research has been done to investigate the relationship between the two. Most musicologists are concerned with musical representation and rhetoric. Some linguists are particularly interested in investigating the structural parallels between speech and music concerning stress and rhythm. Houghton (1984), for example, discussed the structural analogy between language and music from a linguistic approach. Swain (1997) looked at music from the syntactic and semantic point of view. Lerdahl and Jackendoff (1996) also analysed the structure of tonal music with respect to musical phrasing and accentuation by applying the Generative Theory. Nevertheless, the relationship between tone and melody in vocal music has received little attention. Among the very few studies in this area, findings appear to be quite antagonistic – evidence from folktales in Dagaare (Bodomo & Mora 2000) and chants in Kalam Kohistani (Baart 2004) show that tonal distinctions are ignored in songs. Leben (1985) argues that in Northern Ewe music it is not necessary for the melodic contour to conform to the phonological characteristics of the text in order that the intelligibility of the text be preserved. Even in songs written in languages with a more complex tonal system like Mandarin, no consistent correspondence is found to apply obligatorily (Chan 1987, Ho 1998, Ho & Bodomo 2003, Wong & Diehl 1999). The major mapping characteristics are illustrated in Section 2.

2. Findings
2.1. How tone and melody are compared
The concept of relativity is crucial in this study. Any tone can be mapped onto any musical note if it is not preceded or followed by another tone. In other words, matching is judged by the relative pitch transition of two adjacent tones (or more precisely the endpoints of adjacent tones) with respect to their corresponding melody. That is to say, the pitch movement from one tone to another is compared to that of corresponding musical transition.

2.2. Evidence for tone-melody mapping in Canto-pop
Below are the major observations made concerning the tone-tune correlation in Cantonese popular songs:

- It is found that the tonal contour of the lyric corresponds closely to the melody and this does not appear to be accidental:

Fig. 1. Excerpt from 他約我去迪士尼 - Kelly Jackie

- The Cantonese low falling tone (21) has a variant known as the extra-low level tone (11) and is phonetically realized as a level tone in songs:

Fig. 2. Excerpt from 飛女正傳 – Miriam Yeung
Cantonese rising tones, namely the high rising tone (35) and the low rising tone (23) are fully realized phonetically, though they do not require two rising musical notes for the realization. They are mapped to a single musical note.

Mapping only concerns the endpoints or the targets of tones, not the onsets.

Logically speaking, tonal targets of the same pitch height are expected to fit in a ‘flat’ melody. However, this is not the only possible mapping pattern. A level or flat tonal target transition can also be found on an ascending or a descending melody, depending on the pitch levels of the tonal target tiers. Specifically, successive high tonal target sequences (5-5) can be found on a level melody as well as on a falling melody, but unlikely on a rising melody. Successive low tonal target sequences (1-1), on the contrary, can be found on a rising but rarely on a falling melody.

This is referred to as constraint interaction from the optimality-theoretic perspective.

3.1.1. The principle of Optimality Theory

Optimality Theory, a linguistic theory put forward by Prince and Smolensky (1993), postulates that variation in linguistic properties among languages results from different ranking and interactions of the same set of underlying universal constraints. In other words, the surface forms of a language are the most ‘optimal’ outcomes of the resolution of conflicts between competing constraints which are universal and violable, depending on how the constraints are ranked or prioritized in a particular language. This theory was originally developed to address phonological differences among languages. Later on it was also applied and extensively discussed in the area of grammar and syntax as well as other sub-fields of linguistics (Kager 1999, Yip 2002, McCarthy 2002, 2004, Gussenhoven 2004). However, there has been no formal research published on the language-music interface from this theoretical perspective to date.

3.1.2. Constraint families

The concept of constraints varies according to different linguistic theories. In OT, constraints are violable: lower-ranked constraints can be violated when a more important constraint is involved. The optimal output is the one which incurs the least violation of the highest ranked constraints compared to other candidates. Constraints are also universal, i.e. all languages are subject to the same set of constraints. Variation across languages is only the result of different ranking of these constraints.

Constraints are generally categorised into two types, faithfulness constraints and markedness constraints. Faithfulness constraints concern the resistance of an input to change in form, whereas markedness constraints favour unmarked features or structures over marked ones. Similar to faithfulness constraints, correspondence constraints ensure a close corresponding relation between two forms, such as base-redundant and citation-sandhi tone relations.

3.1.3. Some OT constraints used in the analysis of tone-melody mapping

In this paper, some existing OT constraints related to tones are extended and redefined in order to fit in the context of music. These ‘new’ constraints are designed in such a way that the fundamental idea of OT is not violated – constraints are universal and violable. The following are some constraints used in this analysis:

- **NoContour** – No contour tones are mapped onto a single musical note
- **Dep-Tune** – No insertion of musical note
- **Max-Tone** – No deletion of tonal constituents (tonal onset or target)
- **Align-L** – Musical note should align with the left edge of tone
• ALIGN-R – Musical note should align with the right edge of tone
• IDENT-DIR – Direction of tonal target and melodic transitions identical
• UPPER-LIMIT – Pitch should not rise beyond the upper limit of the pitch spectrum or the pitch range which envelops the five phonological pitch levels.
• LOWER-LIMIT – Pitch should not fall below the lower limit of the pitch spectrum or pitch range which envelops the five phonological pitch levels.
• OCP<sub>max</sub> – Identical adjacent musical notes are prohibited (no ‘flat’ or ‘monotonous’ melody).

3.2. OT and the language-music interface

How is “ungrammaticality” exhibited in music? In OT terms, absolute ill-formedness or ungrammaticality refers to the linguistic objects (a phonetic form, a word, a sentence, etc.) which are absent or which cannot be observed in a language. This suggests that these linguistic objects are actually some output candidates which never succeed in being the most optimal ones to get to the surface structure of the language (McCarthy 2002). In the tone-tune interface, “ungrammaticality” is analogical to tone-tune mismatches. Tone-tune mismatches found in Canto-pop are defined as unnaturalness of lyrics, as perceived by native speakers of Cantonese. Before the discussion on OT analysis, it is necessary to note the fact that most of today’s Canto-pop shows optimal tone-tune matching – only 2 out of 50 songs sampled contain tone-tune mismatches, which usually do not exceed 2% of the lyrics. In view of the insignificance of mismatches, these will be ignored in our discussion. The cases to be investigated are all considered as perfect mapping according to the perception of native speakers.

3.3. OT analysis of the data

3.3.1. The dominant constraint in tone-tune mapping

In view of the abundant cases of strict correlation between the melodic and tonal target transitions observed in the data, IDENT-DIR is likely to be the dominant constraint in the operation. The most frequent mapping patterns between citation tone tonal target transition and melodic movement found are shown in Figure 1. These perfect mappings can also be represented as follows:

Fig. 6. Rising tonal target transition – rising melody
Tonal target tier
\[ \begin{array}{c}
\text{Melodic tier} \\
\end{array} \]

Fig. 7. Level tonal target transition – flat melody
Tonal target tier
\[ \begin{array}{c}
\text{Melodic tier} \\
\end{array} \]

Fig. 8. Falling tonal target transition – falling melody
Tonal target tier
\[ \begin{array}{c}
\text{Melodic tier} \\
\end{array} \]

3.3.2. The Cantonese contour tones

As mentioned previously, the contour of the low falling tone of Cantonese is not realized phonetically in Cantopop. This suggests that the NOCONTOUR constraint is highly ranked so that contour of the low falling tone cannot be preserved when mapped to a single melodic tune. It is also proposed that the constraint ALIGN-R requires the right edge of the contour tone be mapped to the musical tune instead of the left-edge. This can account for why the tonal target is retained while the tonal onset is not realised. However, Cantonese rising tones do have full phonetic realization in songs. This contradiction leads to the assumption that the NOCONTOUR constraint has a low ranking, so that even violation of it is tolerated. The following tableaux attempt to illustrate the different treatments of the low falling tone and the two rising tones in Cantonese songs:

Table 1. OT analysis of the low falling tone in Canto-pop

<table>
<thead>
<tr>
<th>NOCONTOUR</th>
<th>DEP-TUNE</th>
<th>ALIGN-L</th>
<th>ALIGN-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 2 1 *!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. 2 1 *!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. 2 1 *!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. 2 1 *</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. OT analysis of the rising tones in Canto-pop

<table>
<thead>
<tr>
<th>MAX-TONE</th>
<th>DEP-TUNE</th>
<th>NOCONTOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>*a. 3 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. 3 5 *!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. 3 5 *!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. 3 5 *!</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.3.3. Pitch-level dependent mapping

Apart from the above patterns of correspondence, irregular patterns are also occasionally found in the data. It is important to call to mind that these ‘irregularities’ do not equate tonal mismatches. Tonal mismatches are considered to be intolerable in perception, while irregularities refer to cases of mapping where IDENT-DIR is not strictly obeyed.

An interesting observation made is that a sequence of two tonal targets at identical pitch level can be found on a falling melody or a rising melody. However, this mapping is far from random. According to the data, H-H tonal target sequences are found plentiful on falling melodies, while M-M sequences are not as abundant in the same musical context. Successive tonal targets at low or extra-low levels with a falling melody are rare in the collected sample of songs. The following OT tableau (Table 3) illustrates the selection process of the optimal melody for the H-H sequence.

Table 3. Melodic candidates for two consecutive high tones

<table>
<thead>
<tr>
<th>5 \ 6 / H – H</th>
<th>UPPER-LIMIT</th>
<th>IDENT-DIR</th>
<th>OCP_MUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Flat</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b. Rising</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Falling</td>
<td>*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is postulated that UPPER-LIMIT prevents the melody going beyond the limits of the phonological range of tones. As shown in Table 3, UPPER-LIMIT has the highest ranking in this array of constraints as far as H-H tonal sequences are concerned. In other words, any violation of this constraint will result in the candidate being eliminated. Candidate (b) in Table 3 incurs a fatal violation of this constraint, and is therefore the least preferred. Similarly, a sequence of two extra-low tones or tonal targets can be found on a rising melody, and frequent examples of this are found in the data. Fewer cases are identified for the M-M sequence, while there is only one case out of 10 songs where a H-H sequence is mapped to a rising melody. This suggests that it is the constraint LOWER-LIMIT which comes into play here, and it is ranked on the very left of the tableau.

3.3.4. Tonal targets and melody in opposite directions

There are also instances in the data where the tonal target transition goes in the opposite direction of the melody. This again is consistently found in a specific context – at word boundaries. If the tones of a sequence of syllables are isolated individually and are sung with the given melody, the string would sound bizarre or even incomprehensible. Nevertheless, when the sequence is put back to the context, it is not perceived as a mismatch. This is explained by the fact that the first syllable of the sequence is in fact the final syllable in a word. Its tonal target is therefore compared to that of the previous syllable, and not to that of the following one. A well-formed mapping is still perceived as long as the tonal target transition of this syllable and the one in front of it complies with the melodic contour.

4. Conclusion

This paper has attempted to account for the observations made concerning the tone-melody relation in Canto-pop songs by adopting an optimality-theoretic approach. Evidence proves that there exists a close tone-melody mapping in Cantonese songs, and the patterns of mapping are very systematic. IDENT-DIR seems to be the dominant constraint, but it may be ranked differently against other constraints in different phonological or morphosyntactic contexts.

This study may be expanded to investigate other genres of Cantones vocal music as well as songs written in other tone languages such as Thai. It is observed that Thai songs also demonstrate a high percentage of tone-melody correlation (Ho 1998). Nevertheless, the way in which tone and melody correspond may not be identical to what we have found in Canto-pop. It would be interesting to see if the same set of constraints are involved in the tone-melody correlation in those songs, and how these constraints are ranked to give such patterns of tone-melody relationship across languages based on the framework of Optimality Theory.

5. References