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Tracking Levels of Closure in Melodies

Andrew R. Brown,[*1] Toby Gifford,[*2] Robert Davidson[#3]

[*]*Queensland Conservatorium, Griffith University, Australia*
[#]*Dept. Music, University of Queensland, Australia*
[1]andrew.r.brown@griffith.edu.au, [2]t.gifford@griffith.edu.au, [3]r.davidson2@uq.edu.au

ABSTRACT

We computationally implemented the *conditions of closure* posited in Narmour's Implication-Realisation (I-R) theory, and evaluated how well these formally defined notions of melodic closure align with points of structural closure – phrase ends and score ends – in the Essen folksong corpus. We found three of the conditions, those relating to durational, metric and tonal resolution, were positively correlated with points of structural closure, and that a combined closure measure calculated from a weighted combination of these individual measures had a strong relationship with structural closure. We suggest this provides evidence supporting the I-R theory's claim that points of positive congruence in these measures can give rise to a sense of repose or completion, or closure in the sense of Gestalt psychology. We provide further detail regarding the strength and independence of the individual conditions in this regard. We conclude that these computationally tractable measures may be of benefit in automated segmentation tasks.

I. INTRODUCTION

At least since Meyer's (1956) discussion of the perceptual importance of expectations in music, researchers have been concerned with measuring varying levels of expectation through the course of a musical piece. A prominent approach to the detailed description of musical expectations is Narmour's (1990) theory of Implication-Realisation (I-R), which suggests implications are suppressed by *conditions of closure* (ibid, p. 11). In this paper we report on our efforts to measure these conditions of closure in the Essen collection of folk melodies (Schaffrath, 1997) and to explore some of the patterns of correspondence and accumulation of these conditions.

In the I-R theory, melodic closure tracks the rise and fall of tension or arousal in a melody. Closure is also associated with melodic structure: Meyer, Narmour and others draw attention to the relationship between closure and structural markers, or boundaries, in melodies. For this reason the tracking of closure levels may have value for melodic segmentation in analytical contexts and melodic continuation and resolution in generative contexts.

Our aim for this research is to gather empirical evidence regarding the veracity of Narmour's closure conditions through computational and statistical musicological analysis. In particular, this paper examines how well these closure conditions align with structural markers, namely phrase ends and score ends. A second motivation for this research is to identify musically effective techniques for algorithmic melody generation.

II. BACKGROUND

In tonal music theory, it is generally accepted that the perceived stability of a melody increases at phrase boundaries, where partial or completed motion towards a goal is articulated by such aspects as harmonic cadence and rhythmic resolution. This stability at phrase endings has long been recognised in music theory and musicology (Riemann, 1900; Schenker, 1973; Cooper & Meyer, 1960; Lerdahl & Jackendoff, 1983) and music perception (Knösche et al., 2005; Palmer & Krumhansl, 1987) and is supported by our own examination of melodies in the Essen corpus.

Meyer discussed melodic closure as a sense of stability or completeness amongst a sea of expectation that contributes to the articulation of structure within the music (1956, p. 129). His ideas were inspired by Gestalt psychological principles including good continuation, which he equated with musical motion or tendency, and which Narmour later codified as one archetype of melodic implication. Meyer speculated on "forces conditioning and controlling a sense of completeness which a melodic pattern gives" (ibid, p. 138) that included 'gaps' in the music, repetition, rhythmic accents and groupings, harmonic stability and registral return. These forces were loosely delineated by Meyer, and found more precise definition in Narmour's rules of implication, and conditions of closure, which we find more amenable to computational modelling and measurement.

A. Narmour's Closure Conditions

The measures of melodic closure we used are based on six 'parametric conditions' of closure outlined by Narmour. These "coinciding musical parameters" are theorised to create an overall sense of melodic punctuation; moments of partial summary, pause, rest or conclusion (1990, p. 11). The six conditions outlined by Narmour relate to the note-by-note circumstances of the melody. They are:

1. a rest or other interruption
2. a point of strong metrical emphasis
3. consonance resolving dissonance
4. shorter note moving to a longer note
5. a larger interval moving to a smaller one
6. a change in registral direction

Previous corpus studies (Schellenberg, 1997; Thompson & Stainton, 1998) have examined related aspects of Narmour's I-R theory (predominantly assessing the predictive power of the implicative principles) and are broadly supportive of the efficacy of the theory. In particular, Thompson & Stainton (1998) find some support for the suppression of implications at points where several of Narmour's conditions of closure are simultaneously satisfied.

III. METHOD

We developed algorithms to computationally measure the closure conditions (excluding the condition relating to the presence of a rest) in approximately 3000 selected melodies from the Essen database (which includes hand-marked phrase boundaries). From these measurements we constructed a correspondence matrix showing the frequency with which these conditions align, and histograms that depict the accumulated co-occurrence at various phrase locations.

We examined the degree of closure at each step in the melody with a view to assessing the level of closure at phrase ends and score ends, where music theory suggests closure should be strong. We measured closure throughout each melody in two stages (described below), then found the mean closure value at the end of a phrase, at the end of a piece, and at any other time.

First, we measured each closure condition separately in order to assess their individual contributions. Second, we measured a weighted combination of closure conditions, where weightings reflected the individual condition's tendency to align with phrase boundaries.

More precisely, for the final combined closure measure, the individual closure conditions were weighted by the statistical significance of the difference in means for closure measures calculated over the population versus at phrase endings.

For the second stage, half the corpus was used as an in-sample population to estimate the weightings, and the remaining half used to as an out-of-sample population to evaluate the weighted combination against hand-marked phrase boundaries.

IV. RESULTS

The measurements show that levels of closure vary throughout the melodies, both in individual strength, and in level of congruence with each other, but the total closure increases significantly at the ends of phrases, and yet more significantly at the ends of pieces, as might be expected.

Figures 1-5 show the frequency histograms for different closure levels in the corpus. Each figure depicts the distribution of levels of a single closure condition, normalised to lie between -1 and 1, with the light, medium, and dark bars representing the distribution of all notes, phrase end notes, and score end notes respectively.

The durational, metric and tonal closure measures (Figures 1-3) all show a significant positive shift in mean closure at phrase ends compared with the entire population, and a greater shift at score ends.

The registral direction measure (Figure 4) shows an inverse effect – the mean closure level shifts downwards at phrase ends, and further down at score ends.

The intervallic change measure also displays an inverse relationship with these structural points of closure. Note however that the great majority of notes had a zero (neutral) value for this closure condition, since the requirements for invoking the condition were infrequently satisfied. Figure 5 depicts a truncated portion of the histograms, so as to allow the structure of the measure to be seen: the middle columns extend significantly further up.

In order to create a combined closure measure, the histograms were used to calculate a statistic reflecting how well each condition corresponded to points of structural closure. The statistic used was the (signed) significance of the shift in means for the histogram, when comparing all notes to phrase ends. In calculating the combined closure measure, each condition was weighted by its value for this statistic. Table 1 shows these weightings.

Table 1. Weightings of individual closure conditions .

	D	M	T	R	I
Weight	0.92	0.18	0.65	-0.17	0.0

Durational closure is weighted most heavily, followed by tonal closure, with metric closure (perhaps surprisingly) receiving a modest weight. The registral direction closure has a modest negative weighting, and the intervallic size closure is too infrequent to gain any weighting under this scheme.

The resulting histograms for the combined closure measure are shown in Figure 6, showing a strong positive relationship between this calculated measure and more traditional notions of closure, namely phrase ends and score ends.

In calculating the histograms for the combined measure, one half of the corpus (the in-sample subset) was used in estimating the weights shown in Table 2, with the remaining half (the out-of-sample subset) was used to calculate the values shown in Figure 6.

We also assessed the level of independence between the individual closure conditions. The registral direction and intervallic size measures were independent of the other conditions. The intervallic size measure was virtually never realised in the corpus, since the definition of the condition requires an unusually large interval to have occurred.

Table 2 shows the correlation matrix for the measured closure conditions of durational cumulation (D), metric emphasis (M), tonal resolution (T), change of registral direction (R) and moving from large to small intervals (I).

Table 2. Correlation matrix between separate closure conditions.

	D	M	T	R	I
D	1.0	0.58	0.37	-0.15	0.0
M		1.0	0.25	-0.07	0.0
T			1.0	-0.11	0.0
R				1.0	0.0
I					1.0

Durational closure is significantly positively correlated with both metric closure (r=0.6) and tonal closure (r=0.3), and tonal closure is mildly positively correlated with metric closure, possibly indicating some redundancy in the closure measures.

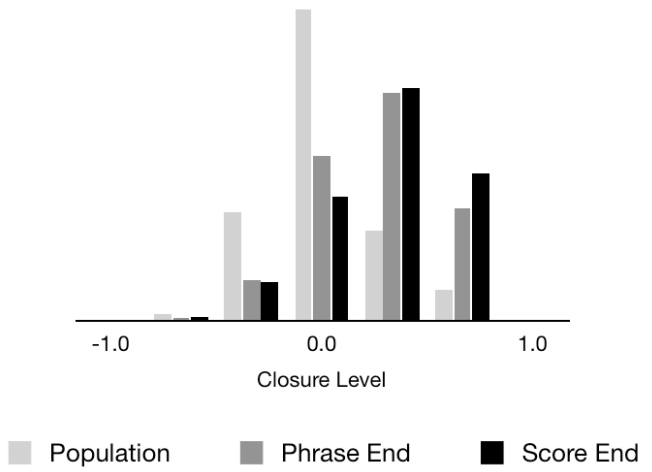

Figure 1. Histograms of durational closure compared at phrase ends, score ends, and entire population of in-sample data.

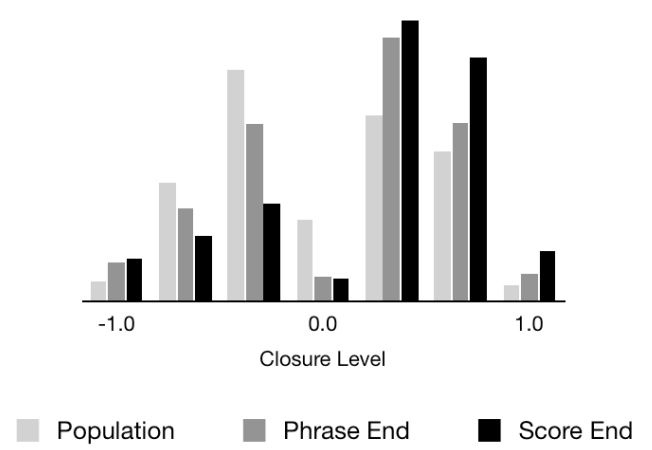

Figure 2. Histograms of metric closure compared at phrase ends, score ends, and entire population of in-sample data.

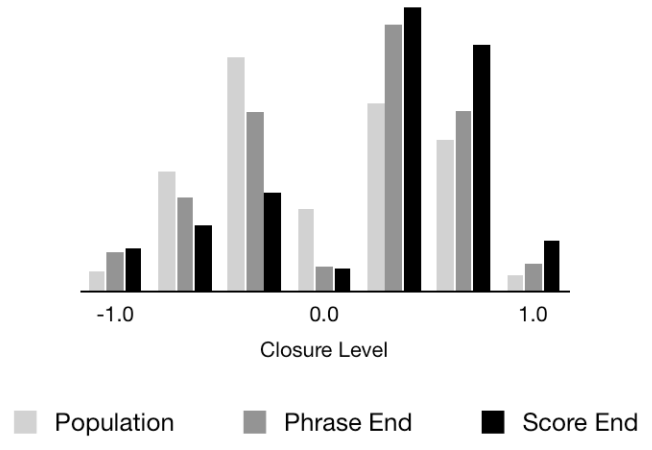

Figure 3. Histograms of tonal closure compared at phrase ends, score ends, and entire population of in-sample data

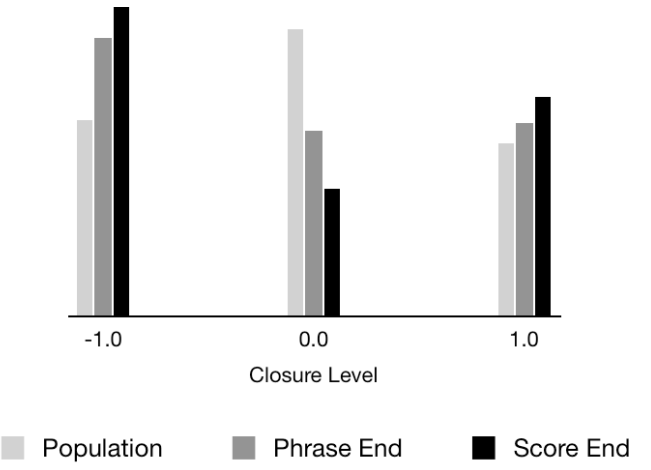

Figure 4. Histograms of registral direction closure compared at phrase ends, score ends and entire population of in-sample data.

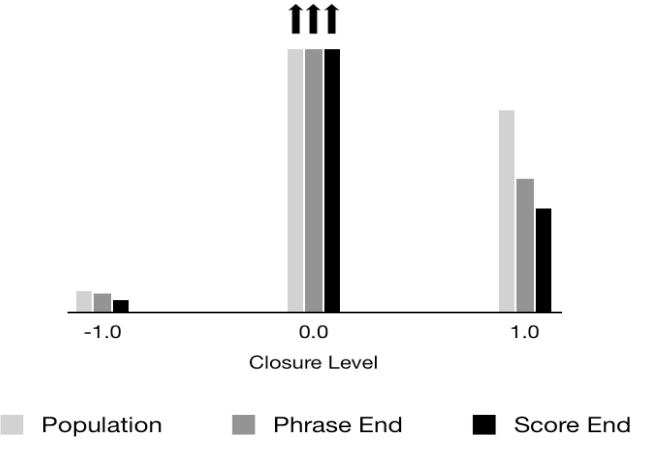

Figure 5. Histograms of intervallic size closure compared at phrase ends, score ends, and entire population of in-sample data.

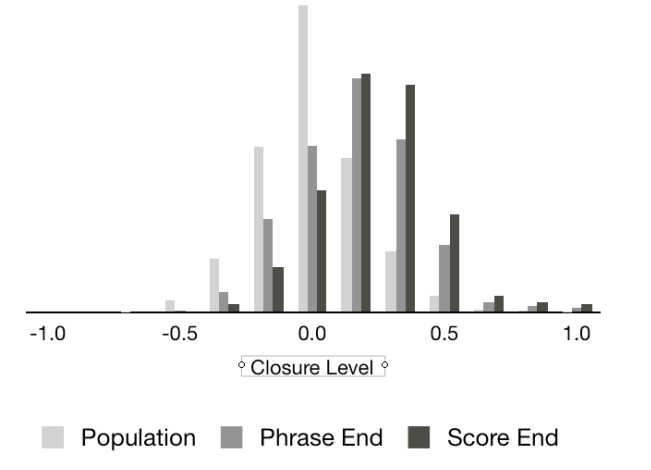

Figure 6. Histograms of combined closure compared at phrase ends and score ends to over entire population, for out-of-sample data.

V. CONCLUSION

We examined various conditions of melodic closure in the Essen corpus of folk songs. In particular we computationally implemented Narmour's melodic conditions of closure (1990, p. 11) enabling automated analysis of the varying levels of these conditions through the songs in the corpus.

These conditions of closure are locally defined properties based on note-by-note transitions: namely (i) movement from a short to long duration, (ii) movement from a point of weak to strong metric emphasis, (iii) movement from dissonance to consonance, (iv) a change in registral direction, and (v) movement from a large interval to a small interval.

We tested the hypothesis that these conditions of closure are related to more traditional notions of melodic closure in music theory, namely points of relative stability, rest, or repose. In particular we examined the behaviour of these measures at phrase endings, and score endings, in comparison to over the whole population of notes.

The individual closure conditions did not align equally with structural markers; the conditions of durational expansion and tonal resolution we the strongest indicators of structural closure.

We found that a combined measure, consisting of a weighted sum of these individual conditions, did indeed have a strong positive relationship with our intuitive sense of structural closure, in which phrase endings are posited to be points of relatively strong closure, and end of pieces even more strongly closed.

The condition relating to a change in registral direction behaved (on average) inversely to our assumptions of structural closure. The intervallic size condition also behaved inversely, though was so infrequent as to not be significant for broad statistical calculations such as this one.

We conclude that it is possible to algorithmically track the level of closure in melodic material, and thus (if one accepts Narmour's I-R theory) concomitantly track implicative strength.

Further we conclude that accumulation of closure measures correlates with phrase endings as might be expected, providing empirical evidence in support of the I-R theory's claim that these closure conditions relate to the Gestalt notion of closure, i.e. a perception of completion, or sense of repose.

Assuming a correspondence between a high level of closure and structural boundaries in melodies, as we have demonstrated, it may be possible to use closure levels as a cue for the identification of phrase boundaries and as a variable in generative music systems to assist in adjusting levels of expectancy or musical stability.

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