DISSONANCE AND TONALITY: THE ROLE OF TIMBRE IN MELODIC RELATIONS

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ABSTRACT

Background. In investigations of the origin of tonal hierarchies of musical cultures the phenomenon of dissonance has been considered of central importance. However, the many models of sensory dissonance that have attempted to account for the preferences of a musical tradition have only proved valid to a certain extent before breaking down in the face of actual musical practice and real listening conditions. So the question beckons; how useful a concept is dissonance in an investigation of the evolution of a musical culture's tonal hierarchy?

Aims. In presenting the limitations of current models of sensory dissonance in accounting for the perceived nature of harmonic relations in the western tonal musical tradition, the case is made for the use of an alternative method of investigation that is more relevant to investigations of musical cultures that are melodically based.

Main Contribution. It is argued that the relationship between the expressive possibilities of an instrument, as reflected in measures of timbre, are important in determining melodic relations in musical creativity worldwide.

Implications. It is proposed that the origin of a musical culture's sense of tonality can be investigated through an analysis of the way in which an instrument's timbral space governs melodic relations and that dissonance is best regarded as one dimension of that timbral space.

1. INTRODUCTION

The concept of dissonance has long been used in investigations of the origin and nature of the tonal hierarchy of Western tonal music. This phenomenon of dissonance has undergone many conceptual changes throughout the history of the western musical tradition, but from the early polyphonic era on it has been used as a means of describing the nature of harmonic tonal relationships. Existing models of dissonance such as those of Kameoka and Kuriyagawa (1969), Hutchinson and Knopoff (1978) and Sethares (1993) are derived from the Helmholtzian concept of dissonance, which is based on beat theory. Such models of sensory *dissonance* or *psychoacoustic dissonance* are potentially useful only in the analysis of harmonic relations. However, as will be discussed in the following sections, these models of dissonance have failed to consistently account even for the perceived nature of certain simultaneous tonal relations in the western tonal system.

A question has, therefore, to be placed over the validity of their application in investigations of the tonal systems of music traditions that are dominated by melodic relations. By exclusively using the concept of dissonance when approaching an analysis of non-western music one is precluding the possibility that other phenomenon may have contributed to the development of its tonal hierarchy.

2. DISSONANCE MODELS CONSIDERED

The two models of dissonance that are referred to in this paper are those of Kameoka and Kuriyagawa and of Sethares. The authors implemented both of these models of dissonance and in doing so met with several difficulties, which indicates limits in their usefulness for investigations of tonal hierarchy. Mashinter (1995) and Huron (2002) noted similar problems with the dissonance model of Kameoka and Kuriyagawa. The following section outlines some of the most significant problems encountered in the above-mentioned models of dissonance.

2.1. Observed Problems

Both the models of Kameoka and Kuriyagawa and of Sethares use, as their basis, the results of an experiment by Plomp and Levelt (1965) on the perception of consonance as a function of the frequency deviation between two sinusoidal tones. This experiment gave rise to the characteristic V-curve for the changes in dissonance as a function of the frequency interval between two sinusoidal tones. Both of the above-mentioned models use Plomp and Levelt's assumption that the total dissonance of a complex can be derived through summation of the individual dissonance of component dyads. In the dissonance models of both Kameoka and Kuriyagawa and of Sethares, this practice is problematic and suggestive of a significant dependence on dissonance of the number of harmonics present in the sound

Both dissonance models attempt to deal with this discrepancy. Kameoka and Kuriyagawa weight the result of every addition using Stevens' power law. The application of this weighting yields dissonance values that increase dramatically with a rise in the number of components in a complex. Sethares approached this problem by weighting each of the dissonance values with the amplitude of the lower frequency component of a dyad. While this practice does ensure that those components of a complex of lower amplitude contribute less to the overall dissonance it also renders the dissonance results very variable as a function of amplitude.

The authors implemented a revised version of the dissonance model derived mainly from that of Sethares. The aim of this model was to investigate the effect on dissonance results of taking account of certain perceptual considerations, most notably the phenomenon of masking. Kameoka and Kuriyagawa

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acknowledged the importance of masking in their calculations and, indeed, took account of the upward spread of masking through comparison of the amplitudes of the components of each dyad. The dissonance model described here takes a different approach by incorporating a psychoacoustical model of masking.

2.2. Further Perceptual Considerations in Dissonance Calculation

In the implementation of this model it was decided to make use of the dissonance calculation specified by Sethares. The model of Kameoka and Kuriyagawa, despite being quite comprehensive, is based entirely on the results of their own experiments and great difficulty was encountered in attempting to replicate their published results. The current dissonance model, incorporates, in addition to the dissonance calculation of Sethares, a psychoacoustical model of masking and also a conversion of the level of the input sound components from dB SPL to phons. The present version of the model is graphically depicted in figure 1.

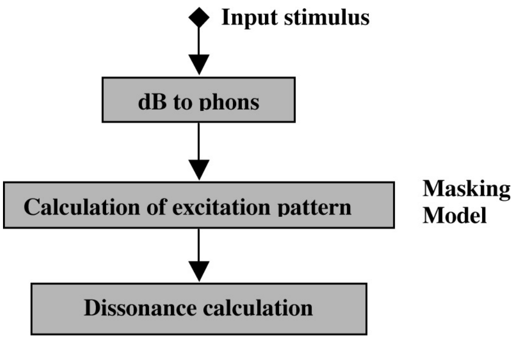

Figure 1: This is a simplified flow diagram of the dissonance model. The application of the model of masking precedes the dissonance calculation.

The equal loudness curves were applied in the decibel to phon conversion through a process of interpolation. The model of masking is implemented through the calculation of the excitation pattern of the input stimulus. The excitation pattern can be described as the output of the auditory filters as a function of the center frequencies (Moore and Glasberg 1990). In the implementation of the masking model it was decided to use a bank of gammatone filters (Patterson 1994).

The dissonance of the input stimulus was calculated in intervals of .023 seconds. This gives a representation of the dissonance over time, which exhibits variations that are dependent on the temporal envelope of a sound and thus its timbre. This similarity between the *temporal* dissonance curve and the temporal envelope of the sound is presented in figures 2 and 3 below for the C4 oboe tone. As will be discussed in the next section, this representation of a sound's dissonance may substantiate the role of dissonance in analysis of non-harmonic relations.

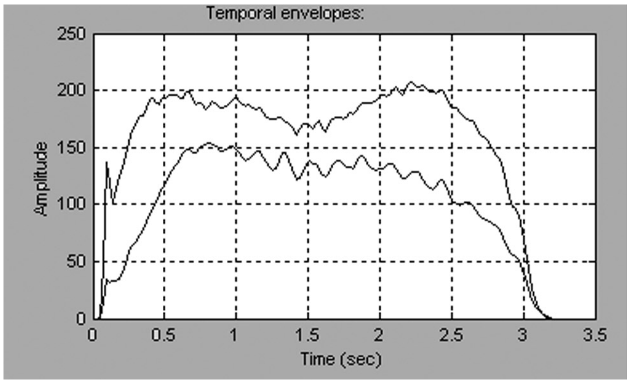

Figure 2: Temporal envelopes of the first 2 partials of a C4 oboe tone.

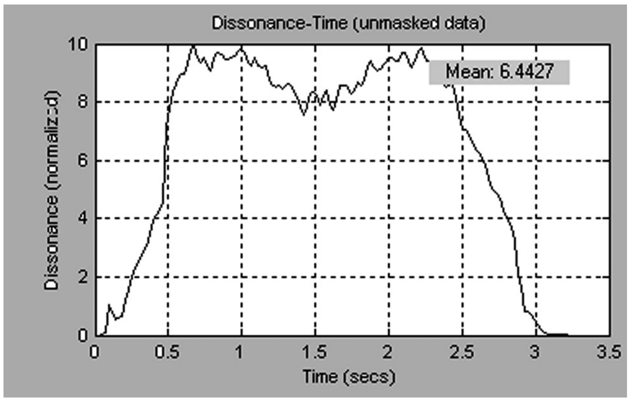

Figure 3: Curve representing normalized time varying dissonance of a C4 oboe tone.

2.3. Investigating the Growth of Dissonance with Complexity

The model was implemented to investigate the effect of increasing complexity on dissonance, as described in the previous section. The results of this investigation are presented below. The increase of the dissonance value as a function of the complexity of the input stimulus is still evident, however, in each example a threshold is reached above which any further increase in complexity ceases to increase dissonance. It was observed that in some cases the dissonance value decreases above this threshold, but this effect is, no doubt, an artifact of weighting the dissonance values of dyads by the product of the amplitudes of the dyad components.

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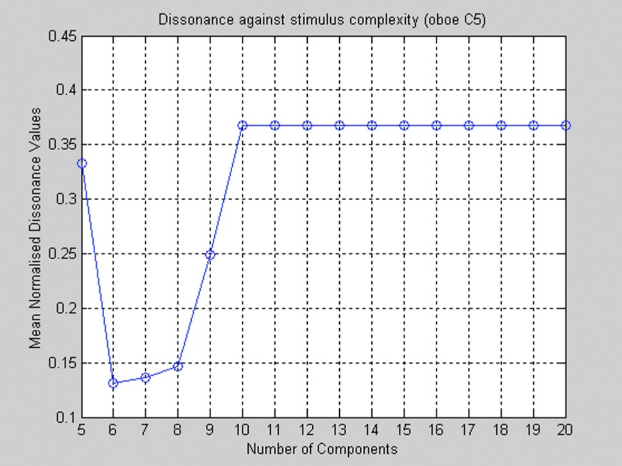

Figure 4: Plot of the increase in dissonance value as a function of the increasing complexity of the stimulus. The stimulus used here is the C5 tone of the oboe.

Huron (2002) introduced the concept of *perceived numerosity* to explain this effect in the results of models of sensory dissonance for chords of complex tones. Huron's proposal is for the involvement of a process of limbic feedback in the decoding of complexity. It is suggested that this process overrides, to a certain extent, the actual sensory dissonance of the perceived complex.

Huron's hypothesis could provide one explanation of the discrepancy between the results of models of sensory dissonance and the actual perceived nature of certain harmonic relations, however, is such a theory necessary? The current model shows that increasing complexity does not necessarily lead to increased dissonance and that this involves the properties of the auditory periphery rather than complex feedback from more centrally involved processes. Also, the modern concept of dissonance derives from the theories of Helmholtz, which, as noted by Tenney in "*A History of Consonance and Dissonance*"(Tenney 1988), should be considered distinct from the functional concept of dissonance presented by Helmholtz's predecessor, Rameau. Because of the dependence of current models of dissonance on timbre, pitch register and dynamics, it would seem that there are limitations to its implementation in the investigation of harmonic relations that have been grounded in the musical tradition of western tonal music for centuries.

3. INVESTIGATING MELODIC RELATIONS

The use of current models of sensory dissonance in the analysis of tonality in non-western musical cultures assumes the central role of harmonic relations in the development of a tonal hierarchy of such musical traditions. Due to the fact that the majority of non-western musical cultures are melodically based, it is proposed that an investigation of melodic relations should be considered in an analysis of the tonal hierarchy of such a musical system.

Assuming that theory follows practice, it is considered that the scales of a musical tradition be considered as abstractions of musical practice; in this case, abstractions of the melodic relations resulting from the interaction of the perceived relations between tones and the timbre properties of the instruments.

3.1. The Role of Timbre

Isolating elements of an instrument's timbre that are useful in the current investigation is of central importance. What are sought are those characteristics of the timbre space that could most likely govern melodic relations. Many researchers have attempted to isolate certain fundamental determinants of timbre. One common denominator of these investigations is the spectral centroid. This refers to the balance of energy in the spectrum of a sound and is most commonly correlated with the dimension of brightness. According to Grey and Gordon (1978) the centroid was found to act as the sole basis in the perception of similarity for the steady state portions of a sound. Kendall, Carterette and Hajda (1999) also referred to its important role as a dimension of timbre The usefulness of this descriptor of timbre in melodic analysis is further reinforced by the experiment of Grey (1977), which concluded that spectral differences between tones are to a certain extent emphasized in a melodic relation. Kendall (2002) also noted the variation of spectral centroid in melodic contexts and in particular the variation of this dimension of timbre with changes in dynamics. Therefore, the main timbre parameter that is used in this investigation is that of spectral centroid.

3.2. The Possible Role of Dissonance

The Helmholtzian model of dissonance does include the possibility of investigating the dissonance of a single sound. Therefore, it may not be necessary to exclude a consideration of a sound's dissonance from the present exploration, instead it is felt that the contribution of dissonance could be taken into account by considering it as another dimension of a sound's timbre space.

The above-described revised model represents the dissonance in a time dependent manner, the form of which is governed by temporal envelope of the sound. Figures 2 and 3 of the previous section present this temporal dissonance. Due to the dependence of the dissonance calculation on the energy of the components as well as the spectral relationships between the components of the sound, a relationship between this calculation of dissonance and spectral centroid also exists. Therefore, it is proposed that a consideration of the way in which the inherent dissonance of a sound influences the perceived melodic relation is possible.

It is also possible to include the role of dissonance by considering the roughness of a sound. Roughness is best described as a temporal form of dissonance and a feature of sound that is exploited in musical expressivity in all musical cultures (Vassilakis 2001), thus dissonance in the form of a sound's roughness is relevant to the analysis of non-western music. The roughness of a sound also contributes to its timbre quality and could thus be considered an element of its timbre space that is exploited in melodic construction.

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In conclusion it is proposed that melodic creation is a function of two inter-relating phenomenon. On the one hand there is the sound-producing instrument itself, which has certain physical properties that govern its timbre and the partition of its related scales (for example, fingering constraints), and on the other hand, the auditory system that perceives these sounds both in isolation and in relation to one another. In melody discrete tones are not perceived as isolated events, but are judged in relation to one another. This relativity between tones is significant in the creation of melody. In addition, a dominant feature of musical practice in all cultures is the exploitation of the timbre characteristics of their instruments. Therefore, it is proposed that the timbre characteristics of an instrument in combination with the perceived relativity of sounds, arising in the auditory system and measured by spectral centroid, dissonance and roughness, are the most important contributors to melodic construction.

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