Expressive dimensions in music

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Abstract. This paper reports on an experiment into musical expressivity in which participants were asked to rate a number of short music pieces along three dimensions correlated with emotional states; valence, power and freedom. Results showed positive correlations between valence and the musical variables of dissonance and noise saturation, as well as between power and the musical variables of note sustain, tempo and reverb. More equivocal results were found for the dimension of freedom, and the musical variable of pitch height.

Keywords: Music, emotion, dimensions, valence, power, freedom, dissonance

1 Introduction

Continuous rating studies, in which participants are tasked to provide temporally continuous judgements of a phenomenon, are now frequently used to investigate correlations between musical features and emotional states [9], [11], [14], [18], (see also [6], [15] for reviews). Such studies have a distinct advantage over those which seek only summary judgements of expressive content since it is clear that the temporally varying nature of music is one of the main reasons it excels in the expression of emotions, and subtle variations as pieces progress can have dramatic effects on our sense of emotional content. It is a further advantage to utilize judgements of specific aspects of emotions, rather than simple emotion labels (i.e. 'happy', 'sad') both because such emotion labels are too general to guarantee their common understanding amongst multiple participants, and because pieces of music do not only become more or less sad, but reveal inflections on those emotions in much more subtle ways [17], [10]. As such the current study extends the continuous ratings approach to some new musical and emotional variables.

2 Emotional Dimensions

Typically continuous rating studies employ a model of emotions based on the two dimensions of valence and arousal, made popular by James Russell and Lisa Barrett [1], [13]. This model is widely recognized by psychologists and other scientists working in emotion related studies as a useful way to quantify emotions. Yet while we agree that the model is convenient to use, we note that it has several conceptual and practical limitations that encourage the use of alternative models, at least as a basis of comparison. Fontaine et al. [4] use factor analysis to show that at least 4 dimensions (which they label valence, arousal, power and certainty) must be used to

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differentiate widely used emotion features (such as behavioural and feeling reports), while Cochrane [2] emphasizes that the dimensions of arousal and valence are not independent of one another, and therefore restrict the affective 'space' that can be effectively mapped. Moreover, valence and arousal are not capable of distinguishing even some of the most common negative emotions such as anger, panic and disgust.

Often a third dimension of 'power' or 'control' is recognized in emotion theories, and so this dimension has been used here as an alternative to arousal. Cochrane [2] also advocates the use of the dimension of 'freedom', since it is ambiguous whether power refers to a state of great strength or energy, or the ability to do what one wants. In common emotion episodes such as anger, these two aspects can be distinguished, since anger is typically a state of great strength or energy, while also involving a sense of constraint. In contrast, an emotion like joy may involve a sense of both great power and freedom. As such a dimension of freedom, specified here as the openness of the world to one's goals, is an important aspect of emotional experience and behaviour and may be usefully applied to our judgements of musical expressivity. At any rate, the use of additional dimensions against which to rate musical samples helps to provide a control for ratings along more popularly used dimensions.

Overall then, three dimensions of valence, power and freedom were employed in this study. Care was also taken to ensure that participants are provided with clear definitions of these dimensions (reproduced in table 1 below).

Table 1. Definitions of the emotion dimensions used in this study, as provided to participants.[1]

Dimension	Definition provided
Valence	By 'positive' and 'negative' character we mean whether the music sounds like a good/bad or pleasant/unpleasant feeling or seems to go with a situation that one would approach or avoid.
Freedom	By 'free' we mean whether the music sounds like a feeling of being able to do things or being open to the world as opposed to 'constrained' where one feels blocked or prevented from acting or shut off from the world.
Power	By 'powerful' and 'weak' we mean whether the music sounds like a feeling of energy/lack of energy or strength/weakness or seems to go with a situation where one is powerful or weak.

3 Method

A flash-based programme was developed by Olivier Rosset, enabling participants to provide continuous ratings of a short piece of music along a single specified dimension. Such a single dimension rating system contrasts with that of Nagel [12] and others, which tasks participants to rate two dimensions simultaneously, but which may not be practical when employing independent and non-standard dimensions, as in this study. Use of flash also allows participants to perform the study online. In this case participants used the computer mouse to adjust the vertical height of a line which

[1] These definitions were also translated into French by Kim Torres Eliard, though in the end only 3 francophone participants were enlisted. The translated text is available on request.

scrolled automatically across the page from left to right as the music played, and which was sampled every 250ms/4Hz. Seeing the line one produces affords the participant a clear sense of their overall judgement of the piece.

Meanwhile, a number of short pieces of music (typically around 30 seconds in length) were composed by Tom Cochrane using MIDI. These pieces were designed to systematically adjust one musical variable such as tempo or reverb while other variables were controlled. As much as possible, musical variables were adjusted in a linear fashion, resulting in a simple increase or decrease of the variable overall. Yet it should be noted that some variables, such as harmonic dissonance, can only be adjusted in a 'step-wise' fashion, while other variables such as reverb, though appearing to increase or decrease in a linear fashion within the confines of the MIDI sequencer, need not necessarily be perceived as such by participants.

For each musical variable, 3 pairs of pieces were provided; where as much as possible, a pair would preserve melodic and harmonic material while the desired musical variable was increased or decreased. Then between the 3 pairs of pieces, care was taken to vary the style, timbre and tonality of the music. For instance, one of the set may be based on a classical style melody, while another would employ a minimalist electronica style. Again (with the exception of pieces testing variances in harmonic dissonance) one piece may be largely in a minor key while another was in a major key, and others in more ambiguous tonalities. Such variation helps to justify the claim that the variables explored are capable of producing expressive variations that are independent of the specific musical context.

In all, 54 short music pieces were composed, designed to test 9 different musical variables. Each of these pieces were then rated on each of the three emotional dimensions of concern in this study. Since rating each sample on each dimension would be a prohibitively time-consuming and monotonous task, participants were randomly split into 3 groups. Each group would then rate 18 of the pieces on one dimension, followed by 18 on the second, then 18 on the third. The order in which pieces were presented within groups was randomized, as well as the order of dimensions ranked (though each dimension was rated as a block, in order for participants to be maximally aware of the nature of the dimension being judged). As mentioned above, very specific definitions for each dimension were provided, which were displayed throughout at the top of the rating window. Participants also had an opportunity to practice the rating task prior to each dimensional group.

Participants were recruited via online mailing lists such as <music-ir@listes.ircam.frm>, <auditory@lists.mcgill.ca> and online psychology forums such as ClinPsy.org.uk, in addition to psychology and philosophy students at Queen's University Belfast. This ensured a good mixture between musical experts and non-experts. The study was carried out between April and May 2011. Participants were not paid, and the results were anonymized. In total 50 participants were recruited, which when split into 3 groups ensured that each sample was rated on each dimension by at least 16 people.

3.1 Measuring Harmonic Dissonance

While most of the musical variables used in this study could be extracted in a fairly straightforward manner from the MIDI sequencer programme. Measuring the degree of harmonic dissonance in a piece requires a much more complex procedure of music information retrieval. In this case, MIDI note information was formatted using MATLAB to show all the notes simultaneously playing at any given moment. Each interval between these notes was then attributed a dissonance score taken from the measure of sensory dissonance adapted for MATLAB by William Sethares [16]. This dissonance score was then multiplied by an additional dissonance score for each individual note playing at a given time. This additional individual-note measure is necessary because the sense of harmonic dissonance in an interval is relative to where that interval lies in relation to the tonic. For instance, in the key of C major, the major third between C and E natural is significantly less dissonant than the major third between Eb and G. This second dissonance score was adapted from the statistical frequency in which different tones appear in musical works, taken from Huron [7] based on the assumption justified by Huron that our sense of how well a given tone fits with the harmonic context determines the frequencies with which that tone tends to be employed in musical works.

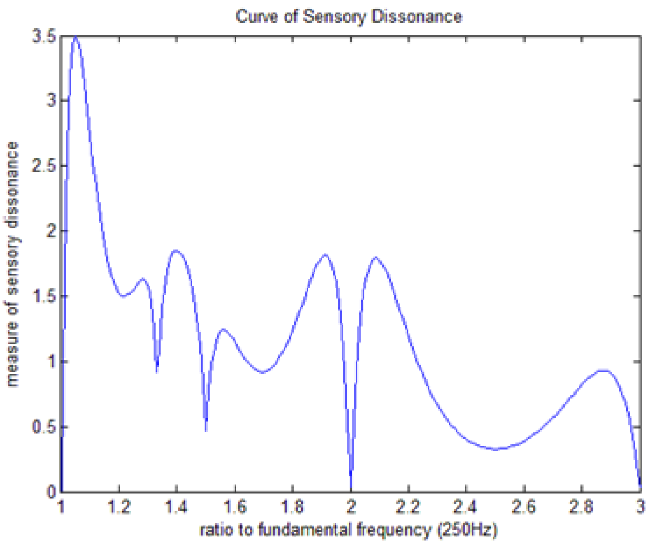

Fig. 3. Sensory Dissonance Curve from William Sethares [16]. The curve shows the level of perceived ‘roughness’ in tones relative to a fundamental frequency (in this case 250Hz). The relation of each tone to the fundamental frequency is expressed as a ratio. So in this case the number 2 on the x axis represents the octave above the fundamental, where 3 represents the fifth above that.

A further variable that was predicted in this study was that levels of harmonic dissonance would be correlated with the sense of emotional valence, but in a non-linear fashion. In particular, it was predicted that the technically most consonant intervals (e.g. simple octave) would be regarded as neutral in valence. The sense of valence should then trace an inverted U or Wundt curve, as dissonance approaches and then recedes from an optimally pleasant sense of harmony (say around a rich major chord). Theoretically, as dissonance moves towards an extreme where it becomes indistinguishable from noise, the sense of valence may again move back towards a neutral level. However, the kinds of tonal intervals used in this study would never approach that degree of complexity. As such, once a linear measure of dissonance was discerned for a piece of music, this was then transformed along the first five sixths of a sine curve- where the neutral starting point is assigned to sine0 and the maximal dissonance is assigned to sine1.572 i.e. 5 radians, the lowest point in the sine curve. The difference in these two measures of dissonance are shown in figures 2 and 3 below, where it can be clearly seen that the transformed dissonance measure closely fits participants' judgements of valence in one of the pieces.

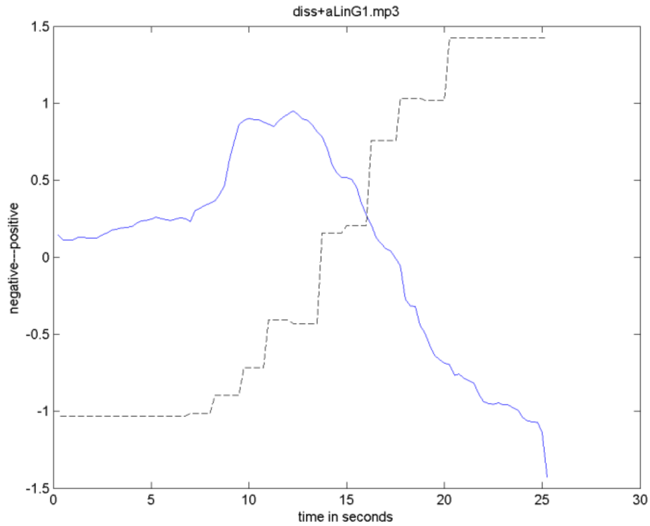

Fig. 2. Dissonance variable (*dotted line*) plotted linearly against participant ratings for valence (*solid line*). Both variables are normalized. Figure shows that as dissonance increases, ratings generally move towards the extreme negative, giving a fairly good negative correlation between the two variables.

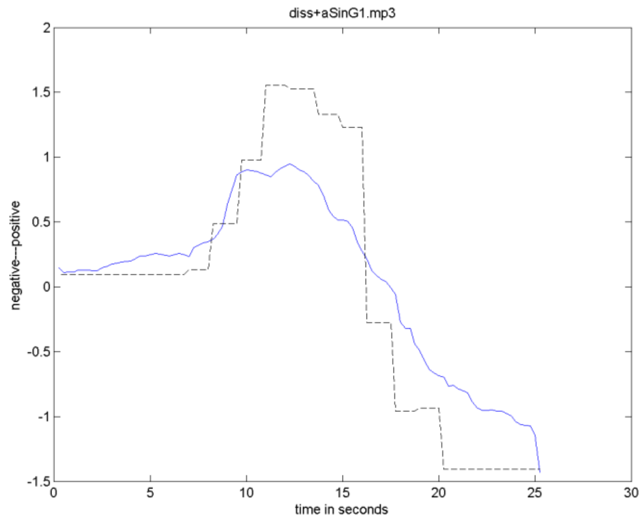

Fig. 3. Dissonance variable (*dotted line*) transformed along values of sine, where the neutral starting point is assigned to sine0 and the maximal dissonance is assigned to sine1.572 i.e. 5 radians, the lowest point in the sine curve.

4 Results

Table 2 below summarizes the results of the rating study for six musical variables of particular interest: harmonic dissonance, noise saturation, pitch height, note sustain, reverb and tempo. For each dimension, the six results are split into those in which the musical variable is increasing (e.g. greater dissonance) and those in which it is decreasing.

Table 2. Correlations (to two decimal places) between each musical variable, and each emotion dimension for 6 separate pieces of music (36 in total).

Music Variable	Dimension	Correlations: Variable Up			Correlations: Variable Down		
Harmonic Dissonance	Valence[2]	0.95	0.77	0.82	-0.18	-0.37	-0.59
	Power	0.56	-0.76	0.21	-0.90	0.77	-0.57
	Freedom	-0.71	-0.74	-0.42	-0.47	0.58	0.80
Noise Saturation	Valence	-0.76	-0.89	-0.92	-0.47	-0.47	-0.22
	Power	0.97	-0.72	0.98	-0.80	0.64	0.30
	Freedom	0.10	-0.88	-0.13	-0.53	-0.84	0.02
Pitch Height	Valence	0.96	-0.31	0.92	-0.08	-0.55	-0.53
	Power	0.07	-0.70	0.76	-0.90	0.95	0.29
	Freedom	-0.64	-0.70	0.96	0.04	-0.91	-0.67
Note Sustain	Valence	-0.90	0.80	0.41	0.97	-0.99	-0.16
	Power	0.79	0.80	0.91	0.93	-0.43	0.91
	Freedom	-0.95	0.81	0.58	0.98	-0.82	0.73
Reverb	Valence	-0.91	-0.97	0.85	0.93	0.91	-0.97
	Power	-0.46	0.63	0.63	-0.89	-0.68	-0.96
	Freedom	-0.37	-0.94	0.42	0.92	0.90	-0.85
Tempo	Valence	-0.73	-0.84	0.92	0.91	0.34	-0.11
	Power	-0.49	0.68	0.68	0.99	0.90	0.94
	Freedom	-0.96	-0.84	0.98	0.89	0.92	-0.64

The correlations between dimensions and variables were then averaged for each set of 3 pieces to reveal which variables are most consistently correlated with which emotion dimensions.

[2] The dissonance measure here has been transformed along the values of sine, as detailed in section 3.1 above.

Table 3. Best averaged correlations (greater than +/- 0.8) across 3 pieces between musical variables and emotion dimensions. Correlations are shown to 3 decimal places.

Music Variable	Up/Down?	Dimension	Correlation	Significance
Harmonic Dissonance	Up	Valence	0.844	P<0.00001
Noise Saturation	Up	Valence	-0.858	P<0.00001
Reverb	Down	Power	-0.842	P<0.00001
Note Sustain	Up	Power	0.836	P<0.00001
Tempo	Down	Power[3]	0.946	P<0.00001

5 Discussion

The results show good correlations between dissonance, noise saturation and the dimension of valence, and between tempo, note sustain, reverb and the dimension of power. The connection between valence and dissonance replicates the findings of several other studies such as [3], [5] and [8] but also adds that the dissonance measure should be adjusted in a non-linear fashion. The expression of valence is further extended to the closely related variable of noise saturation. This is a plausible result since both musical features provide a sense of sensory roughness. Meanwhile, an increase in the sense of power is correlated with the *decrease* of reverb and the *increase* of note sustain. Reducing reverb results in a 'sharper' and 'closer' sound that may be psychologically associated with greater strength or energy,[4] while the increase of note sustain is a factor of loudness, that has already been associated with greater arousal [3]. Again, the correlation of a decrease in tempo with a decrease in power makes sense as a psychological connection between energy levels and one's speed of movement.

Ratings on the freedom dimension only produced good correlations on single pieces, and not as an average of three pieces in a set. In particular, while reverb was predicted to effect the sense of freedom, we see in table 2 that when reverb was decreasing, participants only agreed that it afforded a sense of greater constraint in two of the set of three, and they judged significantly in the *opposite* direction for the third piece. However, we also see that in some pieces of music, a significant rating for freedom is provided that is similar across both the increase and the decrease of the tested musical variable, indicating that some other musical variable in these pieces is consistently affecting the sense of freedom. These pieces are the second 'noise saturation' piece and to a lesser extent the second 'pitch height' piece. These pieces are both made from highly similar musical material which is slow and in a minor key- resulting in a fairly 'sad' sounding piece overall. This connection between the sense of freedom and sad sounding music would be worth investigating further. It was also noted that several pieces characterized by a high level of repetition resulted in low

[3] Note: as tempo goes down, power also goes down.

[4] Note that increased reverb can make a sound seem quieter, though as much as possible this possibility was controlled for in the composition of the reverb-varying pieces.

judgements of freedom, however these results were not very consistent. Again, it would be worth more systematically investigating a possible connection between the degree of repetition and the sense of freedom.

We also did not find strong correlations between pitch height and any emotion dimension. This musical variable was predicted to correlate with valence, but we see significant results only for two of the three pieces in the set. The most likely cause of this is that the second pitch height varying piece is in a minor key, and this sense of tonality probably overwhelmed any positive effect on valence that a rise in pitch may have achieved. The conflict between musical variables in this manner should also be more closely examined in future studies.

It is particularly notable that as a group, participants did not generally agree on the emotional significance of a musical variable where that variable was adjusted in both directions. For instance, where the increase in dissonance was widely agreed to result in a more 'negative' sound, the decrease of dissonance shows more confused results (in this case, one of the 3 pieces did not show a good correlation). Naturally, the fact that an average of the correlations across all judgements on a dimension, regardless of the direction of change, could not generally be obtained, must constrain any bald assertion that a certain musical feature goes with a certain emotion dimension. It is also possible that participants take time to adjust when a piece begins in a very dissonant mode, and only judge a mild sense of 'relief' when that dissonance is gradually removed. More generally however, it may be that adjustments in certain musical features are just more noticeable when they occur in one specific dimension. It would be worthwhile to test the above 'best' correlations in more detail, to explore more fluctuating levels in these musical variables within a longer piece of music.

Finally, it should be noted that while some good results were achieved in this study, there were a few limitations inherent to the experimental design. Naturally, a greater number of music pieces would enable a more robust measure of the dimension of concern. More importantly, listeners only had the chance to rate each piece once. While this would ensure a fresh response, it is not necessarily contrary to good judgements of expressive content to hear a piece over several times, and indeed to have the chance to return to one's judgement after hearing other examples.

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