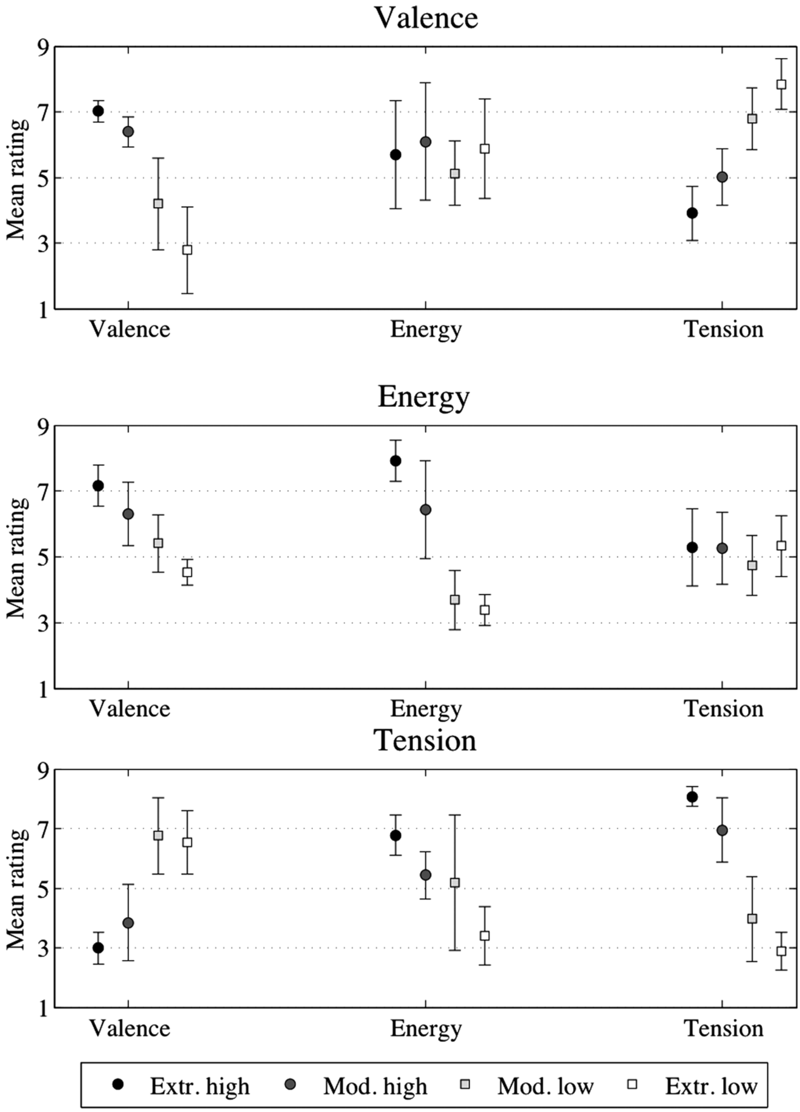

Figure 3. Mean ratings and 95% confidence intervals for 60 examples representing 6 target emotions and 2 levels of the three dimensions.

$_{\mathrm{CI}\ 99.9\%}$ for high examples was .74 $_{.69\ .78}$, and for moderate examples it was .49 $_{.29\ .61}$). Similar analysis was performed for the raw ratings of the three dimensions, and the resulting reliability estimates were also significantly different at $p < .001$ level (mean $_{\mathrm{CI}\ 99.9\%}$ for high examples was .95 $_{.94\ .96}$ and for moderate examples it was .77 $_{.72\ .82}$). Although the reliabilities for both models show significantly lower overall reliabilities for moderate excerpts, presumable as they may be a mixture of several emotions, those for moderate excerpts from the dimensional model are at the same level as the reliabilities for the high excerpts of the basic emotion model, implying a higher overall reliability in the dimensional model ratings. However, perhaps the selection of the basic emotion excerpts is such that they have lower overall reliability in general compared with the dimensional model excerpts and the difference is not in the measurement model. To evaluate this argument, we replicated the same analysis but reversed the concepts (high examples of target emotions selected using the basic emotion model were rated with the dimensional model). The reliabilities and their confidence intervals showed again a similar pattern. For basic emotion model ratings of the dimensional targets, α was $.87_{.85\,.89}$ for characteristic examples, and $.70_{.66\,.74}$ for ambiguous examples. For dimensional model ratings of the basic emotion model targets, the alphas were higher ($.94_{.93\,.95}$ for high examples, and $.85_{.81\,.87}$ for moderate examples). In both cases, significant differences in the reliabilities between the high and moderate excerpts were found but the overall reliability of the dimensional ratings was again higher. So the dimensional model provides somewhat higher inter-rater consistency no matter which way the musical excerpts have been chosen. Whether consistency is a crucial detail in assessing the adequacy of these models is another question. High consistency could for example also indicate that the measurement scale is trivial and thus offers little insight into the actual emotion process.

The applicability of the discrete emotions to the appropriate emotion prototype areas (Russell & Feldman Barrett, 1999) is visualized in Figure 4, where both the strength and the variation of all discrete target emotions are shown as densities in the valence-energy space. Marked in the plot are the target centroids of the chosen high and moderate examples of the five discrete emotions, which indeed lie in the approximate (attractor) areas of high ratings for these emotions. Moreover, the variation demonstrates that the high examples are mostly located within areas of high agreement (sadness and tenderness are the notable exceptions), and the most moderate examples are located in less well-defined areas. In contrast, the deviations in the ratings of the dimensional model are lower and spatially more uniformly distributed, and do not have such ill-defined areas around the attractors of the emotion categories. This is also demonstrated by the means of the ANOVA above. The practical implication of this is that, whereas both models may be used to adequately describe emotional excerpts representing clear examples of discrete emotions, the strength of the dimensional model lies in its ability to describe such emotional examples that lie outside these discrete attractor areas. The utilization of this asymmetry between the models would allow us to explore how a hybrid model of emotions might manifest itself in music (Russell, 2003), and is of consequence to clinically oriented studies that are interested in the patients' processing of emotionally ambiguous examples (e.g., Bouhuys, Bloem & Groothuis, 1995; Cavanagh, & Geisler, 2006).

In the end participants were able to recognize the target emotions represented by the high examples consistently, and in moderate examples the target emotion was confused with at least one other emotion. This has also been observed in previous research, and could be interpreted more generally as fuzziness in the definition of the emotion categories (for examples, see Dailey, Cottrell, Padgett, & Adolphs, 2002; Russell & Fehr, 1994). In the case of the emotion dimensions, the results have to be viewed from a different angle, because here the 'emotion targets' were actually the six bipolar extremes of three dimensions. Instead of concentrating on the confusion between different dimensions, we should focus our attention towards any possible confusion between the bipolar extremes of a given dimension. For example, valence and tension ratings for excerpts representing moderate positive energy did not differ (see Table 2). To set these observations into a wider context, it is necessary to examine the whole pattern of correlations between the emotion concepts.

Patterns of correlations between the emotion concepts. Our intention was to explore how the two dominant conceptual frameworks for emotions in music (dimensional and discrete) can be used

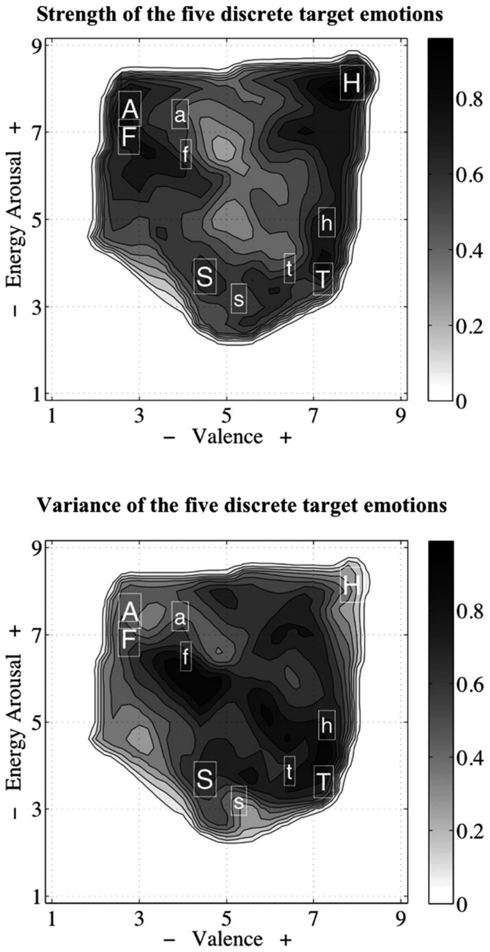

Figure 4. The intensity of each discrete target emotion is shown via accumulated density distribution of the emotion ratings for each category (upper panel). To define each of the five discrete target emotions, the examples that received ratings above the upper 50% percentile of the appropriate target ratings have been selected. The labels refer to the centroids in the valence–arousal space defined by the five discrete target emotion examples (A = anger, F = fear, H = Happiness, T = tenderness, and S = sadness, capitals refer to high examples and small letters moderate examples). The lower panel displays a similar projection of discrete emotion areas within the valence – arousal space, but the gradient indicates the amount of variation (normalized standard distribution of the ratings) for each emotion category. The centroids of the high examples are located clearly on well-defined areas (high intensity and low deviation) whereas the moderate examples are on less clearly defined areas (lower intensity and higher variation).

to describe perceived emotions in music. We also set out to clarify what type of dimensional model would be the most appropriate for such studies. To make this comparison we used a variety of correlational techniques. To begin with, mean ratings for both sets of stimuli were visualized across the three dimensions (Figure 5) and the ratings of the discrete emotion categories were indicated with appropriately sized markers (the greater the marker size, the greater the

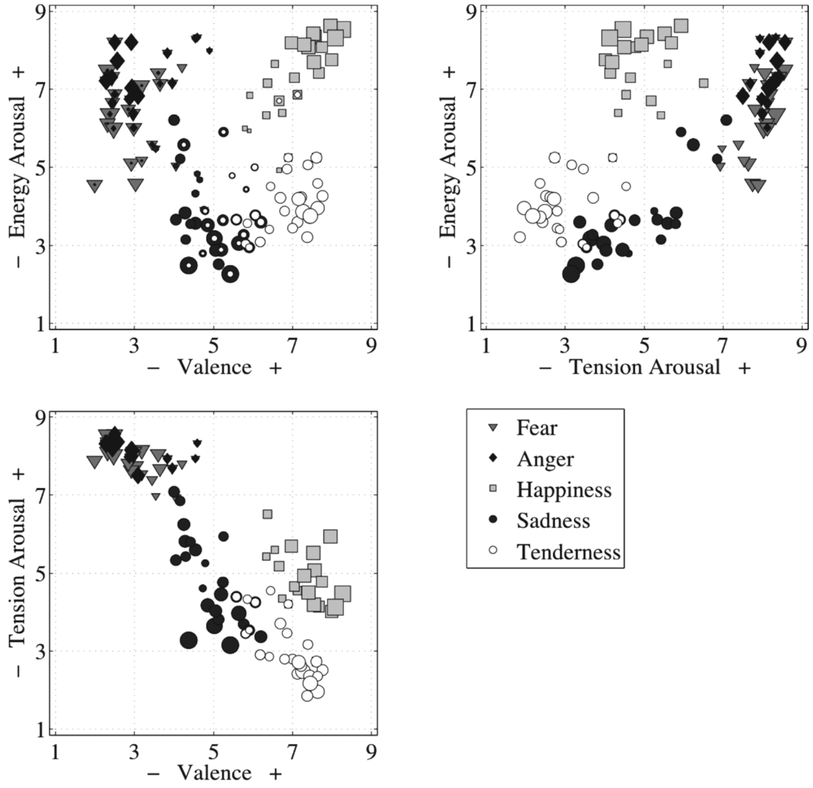

Figure 5. Mean ratings of three dimensions and discrete emotions for all excerpts ($N = 110$). The marker types represent the target emotion categories and the sizes indicate the mean target emotion rating for each excerpt.

mean rating for the discrete emotion indicated by the marker type). The scatterplots in Figure 5 show a highly collinear structure between valence and tension. However, the remaining dimensions display less evident correlational structures. The discrete emotion categories – as represented by marker types and sizes – suggest a clear separation of happy excerpts from the rest of the discrete emotions. Also tenderness and sadness stand out as distinct areas within the dimensional space. None of these three categories overlap with anger and fear, even if these two do so between themselves in the dimensional structure (see Kreutz et al., 2008; Schubert, 1999; Vieillard et al., 2008). As we remember from the analysis of discrete emotion ratings, this overlap was also evident in the ratings of anger and fear, and thus is not a feature particular to the dimensional emotion model alone.

Correlations between the different emotion concepts, together with preference and beauty, are shown in Table 3. Fear and anger can be observed to correlate highly with each other ($r = .69$, $p < .001$), which suggests that these two emotion concepts might not be easily distinguishable in the context of music (Juslin, 2000; Kallinen & Ravaja, 2006). Interestingly, tenderness received higher correlations with sadness ($r = .36$, $p < .001$) than with happiness ($r = .15$), as traditionally tenderness has been associated with positive emotions in general (Juslin, 2001, p. 315). Another noteworthy observation is that valence and sadness did not correlate with each other. This is in line with results obtained by Bigand et al. (2005) and Kreutz et al. (2008), who both discovered that sad music was not systematically associated with negative valence. Although sadness is generally considered to be an unpleasant emotion, the classification is not as straightforward in the context of music. For instance Schellenberg and colleagues (2008) found that, in some instances, sad music was liked as much as happy music. It seems that in music-mediated emotions, happiness and sadness do not represent the opposite extremes of valence: although happiness had a strong positive correlation with valence ($r = .80$, $p < .001$), sadness and valence did not correlate ($r = -.03$). Sad music is often considered beautiful, and therefore it may be difficult to perceive sadness in music as unpleasant. Schubert (1996) has offered a theoretical solution to this dilemma using a neural inspired associative network model, in which negative emotions in an aesthetic context may activate enjoyment. In fact, it has even been reported that sad music activates neural networks involved in biological reward (Blood & Zatorre, 2001). For example, sadness correlated with preference ($r = .38$, $p < .001$) and beauty ($r = .59$, $p < .001$) significantly more highly than happiness ($r = .22$, $p < .05$; $r = .16$). However, tenderness and valence correlated with preference ($r = .58$, $p < .001$; $r = .56$, $p < .001$) and beauty ($r = .77$, $p < .001$; $r = .61$, $p < .001$) even more highly than sadness. Lastly, the ratings given by the participants in the main experiment were to a great extent similar to the ratings given by the small group of experts in the pilot (the final row in Table 3).

When comparing our results to earlier studies of the three-dimensional model (conducted in non-music contexts) we find there are certain differences, particularly when the correlations between separate dimensions of the models are taken into account. For example, in a study based on current mood ratings, Schimmack and Grob (2000) found a strong positive correlation between energy and valence ($r = .49$), a strong negative correlation between valence and tension ($r = -.70$), and a moderate negative correlation between tension and energy ($r = -.33$). In our study, energy and valence did not correlate with each other ($r = -.08$), valence and tension had a very strong negative correlation ($r = -.83$), and tension and energy had a strong positive correlation ($r = .57$). This might be due to the different qualities of music-mediated emotions compared to mood or everyday emotions, but there are no other points of comparison from the field of music-mediated emotions. Another possible cause for the difference is that, despite our efforts of sampling the three-dimensional space in a systematic manner, the chosen sound examples may have represented the geometric space in a different way to how it was

Table 3. Correlations between the concepts (*N* = 110).

	Happiness	Sadness	Tenderness	Fear	Anger	Valence	Energy	Tension	Pref.
Sadness	−.48***								
Tenderness	.15	.36***							
Fear	−.61***	−.28**	−.67***						
Anger	−.41***	−.31**	−.58***	.69***					
Valence	.80***	−.03	.63***	−.91***	−.71***				
Energy	.44***	−.79***	−.64***	.28***	.47***	−.08			
Tension	−.42***	−.38***	−.87***	.87***	.75***	−.83***	.57***		
Pref.	.22*	.38***	.58***	−.63***	−.37***	.56***	−.31***	−.63***	
Beauty	.16	.59***	.77***	−.73***	−.56***	.61***	−.58***	−.81***	.87***
Experts†	.94***	.88***	.90***	.93***	.92***	.86***	.90***	.94***	

Notes:*** $p < .001$; ** $p < .01$; * $p < .05$; †Correlation with the ratings of the experts from the pilot experiment for the same 110 excerpts.

represented in the previous studies. For instance, we have relatively few examples of excerpts representing low tension and negative valence, as the correlations suggest that these variables mostly co-varied. At this point it is difficult to conclude whether this phenomenon is specific to music or the particular set of stimuli we used, as we do not have alternative samples of stimuli at our disposal. Nevertheless these correlations, as well as the figures, hint at a possible reduction of the three-dimensional model. We will address this issue after first making a direct comparison of the discrete and dimensional approaches.

Correspondence between discrete and dimensional models of emotions. To assess the compatibility of the two main conceptual frameworks for emotions in music, we adopted two correlational techniques, canonical correlation and regression. In the canonical correlation, the interdependency of the two frameworks could be measured in a single analysis. This analysis provided three canonical variates. The first canonical correlation was .99, the second .94 and the third was .57, and the model with the three canonical correlations included was highly significant, χ^2 (15) = 634.05, $p < .0001$. The first three pairs of canonical variates accounted for a significant relationship between the two sets of variables. Data on the canonical variates are displayed in Table 4. Indicated in the table are correlations between the variables and canonical variates, within-set variance accounted for by the canonical correlations (percent of variance), redundancies and canonical correlations. Total percentage of variance indicates that the third canonical variate was minimally related to the two sets of variables and therefore the interpretation of the third pair is questionable, even though this variate was also statistically significant ($\chi^2 = 41.80$, $p < .001$). The interpretation of the first canonical variate can be drawn from the correlations, indicating that the variate may be labelled as valence (inverted). This is because tension (.88), fear (.94) and anger (.75) as well as valence (–.98) are projected with high loadings onto the first variate. The second canonical variate could then be labelled as activity (inverted). This is because energy (–.92), happiness (–.64), and sadness (.85) receive the highest correlations with the second canonical variate. The interpretation of the third canonical variate is precarious due to the low percent of variance that can be explained (0–5%). This analysis as a whole puts forward the notion that the two conceptual frameworks are largely similar and the minimal description of this mapping might reasonably have a two-dimensional structure.

In the second conceptual comparison, we employed regression to predict the dimensional ratings from the discrete ratings and vice-versa. This technique has the advantage of providing a well-known measure of fit (R^2). As all 110 music examples were rated using both conceptual frameworks, such a comparison was possible. Knowing that relatively high correlations exist between the emotion ratings, collinearity of predictors was evaluated using a variance inflation factor (VIF) for each set of predictors (basic emotion and dimensional models). For basic emotion ratings, all VIF values remained lower than the suggested threshold value for collinearity (10; see Cohen, Cohen, West, & Aiken, 2003, p. 423) but for valence, energy arousal and tension arousal, VIF values indicated high collinearity (11.4, 5.3, 16.9). For this reason, the regression estimates for each basic emotion concept with the dimensional model ratings as predictors was performed using ridge regression. This technique is less influenced by collinearity due to the inclusion of constant variance parameter (λ), which attenuates the influence of collinearity in the calculation of the least squares optimization in regression (Cohen et al., 2003). In this case, optimal λ was set at 50 (three predictors) and 100 (two predictors), which was established by 10-fold-over cross-validation with this data. The results – displayed in Table 5 – demonstrate that the discrete emotion model can more accurately explain the results obtained with the three-dimensional model than vice-versa. This may partly be due to the higher amount of explanatory

Table 4. Correlations, canonical correlations percents of variance and redundancies between dimensional and categorical ratings and their corresponding canonical variates

	1st Can. Var.	2nd Can. Var.	3rd Can. Var.
Dimensional			
Valence	–.98	–.11	.04
Energy	.20	–.92	–.03
Tension	.88	–.37	–.13
Percent of variance	.59	.33	.00
Redundancy	.57	.29	.00
Categorical			
Happiness	–.75	.64	.05
Sadness	–.07	.85	.05
Tenderness	–.71	.53	.33
Fear	.94	–.11	.94
Anger	.75	–.37	.42
Percent of variance	.51	.31	.06
Redundancy	.49	.30	.05
Canonical correlation	.99	.94	.57

variables (five) but also the fact that discrete emotions are an easier concept for the general public to understand than emotion *dimensions*. Nevertheless, the difference between the mean prediction rates of the models (displayed in Table 5) is not large (17%) and this considerable degree of overlap between the conceptual frameworks is noteworthy considering that neurological evidence has suggested that separate processes might be involved (Dellacherie et al., 2008), and that it is only relatively recently that both models have started to occur within the same study.

To examine the validity of the three-dimensional model, the coefficients of determination for it were also compared with the circumplex model (Russell, 1980) and the multidimensional model of activation (Thayer, 1989). The results suggest that these two-dimensional models can explain the results obtained with the discrete emotion model virtually as accurately as the three-dimensional model, with the exception of anger (see Table 5). The differences between the prediction rates of the three alternative dimensional models were evaluated using a comparison of the difference between two multiple correlations (Steiger, 1980), which involves transforming the multiple correlations of the predicted models into Z scores and adjusting for mutual correlation and sample size (Tabachnick & Fidell, 2001, p. 146). This analysis yielded significant differences between all the different prediction rates of the models (see Table 5). It is worth pointing out that, in comparison to other emotion categories, sadness was explained equally modestly ($R^2 = .63$) by all dimensional models. This may reflect the participants' difficulty with rating the valence of sad music, as previously mentioned. Despite this irregularity, these analyses suggest fairly high mutual correspondence between the two conceptual frameworks and stimulus sets, and further suggest that the common denominator between these frameworks might be two-dimensional.

A requisite number of dimensions. The previous summary of the correlations between the emotion ratings suggested high collinearity within the three-dimensional model (the overlap between valence and tension). To examine whether the three-dimensional model could be reduced to two dimensions, the independence of the three dimensions needed to be scrutinized.

Table 5. Regression summary of dimensions and discrete emotions explaining discrete and dimensional emotion ratings ($N = 110$)

	R^2 (β)		
	3D	2D (Russell)	2D (Thayer)
Dimensions as predictors (valence, energy, tension)			
Happiness	.89 ($V_{0.93}$, $E_{0.79}$, $T_{-0.35}$)*	.89 ($V_{0.85}$, $E_{0.49}$)*	.86 ($E_{0.64}$, $T_{-0.62}$)
Sadness	.63 ($V_{-0.20}$, $E_{-0.84}$, $T_{-0.22}$)	.63 ($V_{-0.05}$, $E_{-0.69}$)	.60 ($E_{-0.65}$, $T_{-0.13}$)
Tenderness	.77 ($V_{0.33}$, $E_{-0.45}$, $T_{-0.58}$)**	.74 ($V_{0.50}$, $E_{-0.51}$)	.77 ($E_{-0.34}$, $T_{-0.61}$)**
Fear	.87 ($V_{-0.83}$, $E_{0.07}$, $T_{0.63}$)**	.87 ($V_{-0.90}$, $E_{0.24}$)**	.74 ($E_{0.03}$, $T_{0.85}$)
Anger	.64 ($V_{-0.52}$, $E_{0.32}$, $T_{0.35}$)**	.68 ($V_{-0.55}$, $E_{0.35}$)**	.54 ($E_{0.22}$, $T_{0.52}$)
Mean R^2	.76	.76	.70
Discrete emotions as predictors (happiness, sadness, tenderness, fear, anger)			
Valence	.97 ($H_{0.35}$, $S_{-.11}$, $T_{0.20}$, $F_{-0.50}$, $A_{-0.14}$)		
Energy	.88 ($H_{0.47}$, $S_{-0.32}$, $T_{-0.42}$, $F_{-0.05}$, $A_{0.36}$)		
Tension	.93 ($H_{-0.29}$, $S_{-0.23}$, $T_{-0.55}$, $F_{0.18}$, $A_{0.12}$)		
Mean R^2	.93		

Notes: β = Standardized beta coefficients. For predicting basic emotions with emotion dimensions, ridge regression was used ($\lambda = 50$ for 3-dimensions, and $\lambda = 100$ for 2-dimensions). For all models, F tests were significant at $p < .001$. Asterisks denote significant difference between the regression models within each categorical emotion (** at $p < 0.01$ level; * at $p < 0.05$ level).

For instance, Roberts and Wedell (1994) have aptly demonstrated that the amount of dimensions needed to explain common mood terms is influenced by stimulus density. In their study, the common two-dimensional solution (valence and arousal) was not sufficient when a core set of mood terms were supplemented with terms representing variants of anger and fear. In the present study, two different types of reductions could be attempted: energy and tension dimensions could be collapsed into one arousal dimension (Russell & Feldman Barrett, 1999) or energy and valence, and tension and valence could both be collapsed into separate dimensions, forming another two-dimensional construct (Thayer, 1989). The plausibility of these more parsimonious models could be investigated by looking at the partial correlations between the dimensions or by testing these explicitly with separate structural equation models. However, when the intercorrelation between the model predictors is high (> .85), it is known to pose severe problems for such iterative models that are based on a covariance matrix (Kline, 2004). Therefore we resorted to a simpler strategy and looked at the partial correlations.

To investigate reducing three dimensions into the traditional two dimensions of valence and arousal (Russell, 1980), we checked whether tension and energy, which correlate positively (.57), could be collapsed into a single arousal dimension by partialling out the contribution of the valence dimension. This analysis yielded a partial correlation of $r_{te.v} = .90$ ($p < .001$), indicating a considerable overlap between the concepts. As valence and energy did not correlate significantly (–.08), we consequently received support for the traditional two-dimensional model. Note that this is in contrast to the results obtained by Schimmack and Reizenstein (2002), who used structural equation modelling to test the independence of the energy and tension dimensions by controlling for valence, and they found no correlation between the residuals of the energy and tension dimensions.

The other two-dimensional model (Thayer, 1989) casts valence into two separate dimensions that consist of energy and tension. As we know from the first order correlations, valence and tension correlate highly ($r = -.83$), but if we control for the contribution of energy then this high correlation might be revealed to be spurious. Nevertheless, valence and tension correlate even more highly when the energy ratings are partialed out ($r_{vt.e} = -.95$), suggesting that at least the high collinearity is not affected by the energy dimension. Partialling out the tension from the correlation between energy and valence also makes them correlate even more highly ($r_{ev.t} = .85$), lending further support for the possibility of dimensional reduction. In sum, both theoretically derived ways of reducing the three dimensions into two are supported by these analyses although the difference between the two reductions is not discernible.

A requisite number of emotion categories. We may also ask whether the ratings of the five discrete emotions contain significant overlap. In comparing conceptual frameworks using regression, we already observed that three to five discrete emotions were necessary to explain over 90% of the ratings in three dimensions. We also noticed how fear and anger seemed to overlap ($r = .69$) when looking at the first order correlations. Here we looked again at the partial correlations by controlling the contribution of the other three discrete emotions while examining the correlation of each pair of discrete emotions. Table 6 displays the results of such analysis. The most striking partial correlations can be seen between happiness, sadness, and fear, all negative and highly significant. This implies that if we removed the ratings of happiness from the data, we would still be able to deduce that happy examples are those which are rated low on sadness, anger, and fear. The case of fear is more complicated, however, as it correlates with sadness and tenderness and so its removal could not be entirely constructed from the three other remaining discrete emotions. Interestingly, fear and anger do not correlate with each other when the other discrete emotion categories are partialled out. It seems that the contribution of happiness ($r_{fa.h} = .60$, $p < .001$) and sadness ($r_{fa.hs} = .18$, $p =$ ns) is enough to create this effect. Thus, the overlap between happy and sad examples indicates that the real simplification of the discrete emotion model may be in terms of the valence dimension. From the previous canonical correlation and regression analysis we already know that this is a viable way of reducing the number of variables in question. Nevertheless, the issue needs to ultimately be considered in a larger context where the purpose of the measurement model can be taken into account.

Discussion

The results of the experiment suggest that the three-dimensional model of emotions may be collapsed into a two-dimensional one when applied to music. The support for this interpretation comes from (1) canonical correlations that highlighted two canonical variates which could account for the correspondence between the discrete emotion and dimensional models, (2) regression analysis which demonstrated that the ratings of discrete emotions may be recovered to a large extent by a two dimensional model (≈80%) and vice versa (≈90%), and (3) analysis of partial correlations, which emphasized the high correlational nature of valence and tension. Nevertheless, the two possible formulations of the two-dimensional model could not be clearly ranked using these analyses, although the canonical correlations indicated that the version by Russell (1980; valence and arousal) was somewhat more appropriate. Also, the regression approach suggested that the version by Russell was slightly better in accounting ratings of discrete emotions (mean $R^2 = .76$), than the alternative version by Thayer (1989; mean $R^2 = .73$).

These results are in contrast to the ones obtained by proponents of the three-dimensional model (Schimmack & Grob, 2000; Schimmack & Reisenzein, 2002), though we must emphasize the main differences between the design of our study and theirs. Schimmack and Reisenzein

Table 6. Partial correlations between the ratings of basic emotions ($N = 110$)

	Happiness	Sadness	Tender	Fear
Sadness	–0.88***			
Tenderness	–0.50***	–0.34***		
Fear	–0.84***	–0.73***	–0.63***	
Anger	–0.39***	–0.39***	–0.34***	–0.08

Note: The contribution of all other discrete emotions has been partialled out except the two (row and column) used in the comparison. *** $p < .001$.

(2002) used a questionnaire study with a large number of questions (18) that covered the affect dimensions with several questions (three for each polar extreme). This allowed them to construct and test latent variables from the separately observed variables using structural equation modelling. Also the ratings of their study were based on current mood, and there was no stimulus or manipulation of mood. In our study the ratings were given to emotions that the participants thought the excerpts conveyed, and the excerpts were selected to portray discrete emotions and polar extremes of the dimensional model. Because of this, the observed emotion structure reflects more directly the stimulus structure. It should also be noted that, despite our careful attempts to control the dimensions when selecting excerpts for the experiment based on the results of the pilot experiment, valence and tension were already correlated. Therefore it is difficult to estimate whether it is even possible to separate these dimensions in musical examples. In other words, the question remains as to whether there is an abundant number of musical pieces that could be highly tense and highly positively valenced at the same time. This is therefore something that needs to be studied further.

General discussion

The work presented in this article aimed to systematically compare distinct models of emotion. Although a small number of previous studies exist where discrete and dimensional data have been collected (Gosselin et al., 2006; Kreutz et al., 2008; Vieillard et al., 2008; Zentner et al., 2008), these have been incomplete with regard to the structure of emotion due to their (1) reliance on discrete emotions only, (2) focus on unambiguous exemplars, or (3) insufficient stimulus quantity. Here the set of musical stimuli was carefully selected in a large pilot study to represent emotion concepts in the dimensional as well as the discrete emotion model. Moreover, both models were represented not only by the clearest examples, but also by more moderate examples. This provided subtle nuances for emotion recognition and linear geometry for comparing the two conceptual sets using linear mapping methods.

The comparison of discrete and dimensional models yielded interesting results. Initially we thought that the discrete emotion model would lead to more consistent ratings of emotions than the dimensional model because the terminology (sad, happy, angry, etc.) is already familiar to participants due to their prevalence in the everyday language of the general public. But this was not observed in the data, as the overall consistencies between the ratings in the dimensional and discrete models did not exhibit any substantial differences. However, the discrete emotion model was clearly less reliable in rating excerpts that were ambiguous examples of an emotion category when compared with the dimensional model. This has direct implications for studies that seek to (1) explore mixed emotions (e.g., Hunter et al., 2008), (2) understand the provocative differences in neural processes between dimensional and discrete emotion ratings (e.g., Gosselin et al., 2006), (3) examine processing biases exhibited by clinical populations to inherently ambiguous emotion stimuli (e.g., Bouhuys et al., 1995), or (4) attempt to clarify the way conceptual decisions are made within the framework of the hybrid model of emotions. For such studies, it is important to be aware of this asymmetry in the reliability of the ratings between the two models.

Despite the discrepancy in the resolution between the models, a high correspondence between the discrete and dimensional models was observed. Probably a large part of the assumed differences between the models has been caused by methodological differences. In many of the previous studies on discrete emotions (Dellacherie et al., 2008; Kallinen, 2005; Khalfa et al., 2008b), a forced-choice paradigm is used in emotion recognition. In the present study, all discrete emotions were available in the form of Likert scales, allowing more subtlety in definition than in a forced choice. In this way the methodologies used in both emotion models were similar and thus were perhaps more likely to lead to converging results.

Another way of representing the high correspondence between the two conceptual models is to consider a hybrid model of emotions (Christie & Friedman, 2004; Russell, 2003). This model uses the components of a dimensional model (valence and arousal) to explain the underlying affect space, which is mainly physiologically driven. When the changes in these core affects are interpreted consciously, however, discrete emotion terminology is used to label the emotional experiences. In this way common discrete emotions can be regarded as attractors or hot spots in the affect space. This view is entirely compatible with the results of our experiment – due to the selection of moderately and highly representative examples of discrete emotion categories – and these attractors are explicit in the figures portraying the excerpts along the three dimensions (see Figures 4 and 5). This model could also be used to characterize the main difference between the utilitarian and aesthetic emotions (Scherer, 2004). Whereas the utilitarian emotions such as fear or anger have specific connections to underlying physiology due to the adaptive function they have (in order to protect the physical integrity of the individual), aesthetic emotions do not. Indeed most of the domain-specific emotions established by Zentner et al. (2008) concern positive emotional responses and match the established functions of music as a reminder of past events (North, Hargreaves & Hargreaves, 2004), or have a direct correlate in a core affect (e.g., joyful activation).

The comparison between different versions of the dimensional model indicated that two dimensions are probably sufficient to represent perceived emotions in music. Nevertheless, this should still be studied further as the stimuli in our experiment were initially chosen to represent each of the six dimension extremes separately. Therefore the tense examples in the selection were also the ones which were often negatively valenced. A random sample of a large corpus of music that is known to manipulate emotions could be used to test for the validity of the three-dimensional model in music. Intuitively, the additional dimension of tension makes perfect sense and a great deal of the effects of music deal with patterns of tension and release (Lerdahl, 2001). Moreover, the tension dimension did actually vary independently for certain discrete emotion categories (e.g., sad examples in the lower panel of Figure 5). Tension is also one of the nine factors in the GEMS model of music-induced emotions (Zentner et al., 2008). Whether the other factors in GEMS model actually correspond with the traditionally used terms (sadness, tenderness, peacefulness, and joyful activation to name the obvious ones) is an interesting future research question. Therefore in our opinion, more research as to the specific dimensions required to represent emotions in music is warranted.

In light of the results obtained in this study, we should also investigate more thoroughly the influence of individual factors on the processing of music-mediated emotions, such as personality and musical expertise. It would also be important to evaluate the degree of mismatch between perceived and felt emotions. That would entail changing the rating instruction towards induced emotions but should also incorporate physiological measures, in which significant steps have been recently taken (Baumgartner, Esslen, & Jancke, 2006; Roy, Mailhot, Gosselin, Paquette, & Peretz, 2008; Withvliet & Vrana, 2006). Another important issue is the limitation imposed by the musical style used. Although film music makes use of stereotypical conventions from the romantic era of classical music, as well as more recent ways to use artificial sound schemes and elements from popular music, it has to be acknowledged that the results could well be different with other genres such as pop or jazz. The genre-specificity and stimulus density effects are two related questions that warrant further systematic research in the near future. Also, a thorough dissection of the acoustical and musical features of the stimuli should be carried out in order to address some of the focal issues that have been raised by the study (mixed feelings, the role of timbre, small differences in fear and anger, etc.). Finally, non-verbal methods (such as paired similarity ratings) could give crucial insights into the requisite number of emotion dimensions and categories (Bigand et al., 2005; Vieillard et al., 2008), provided that the initial coverage of the stimuli is reasonably varied (Roberts & Wedell, 2004).

In conclusion, our study demonstrated that discrete and dimensional models of emotion produce highly compatible ratings of perceived emotions, when using a large, systematically chosen set of authentic music from film soundtracks. We also highlighted the noteworthy differences between the models that mostly relate to the constrained resolution of the discrete emotion model. In these respects, our study provides a useful point of reference for exploring the connections between the recognition, experience and physiological manifestations of emotions, as well as the individual variables that moderate all of these.

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Notes

1. https://www.jyu.fi/music/coe/materials/emotion/soundtracks/
2. https://www.jyu.fi/music/coe/materials/emotion/soundtracks/

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Appendix. List of audio tracks used in Experiment

No.	Emotion & level	Album name	Track	Min:Sec
001	Anger high	Lethal Weapon 3	8	04:15–04:29
002	Anger high	The Rainmaker	7	01:45–02:00
003	Anger high	The Alien Trilogy	9	00:03–00:18
004	Anger high	Cape Fear	1	02:15–02:30
005	Anger high	The Fifth Element	19	00:00–00:20
006	Anger mod.	Crouching Tiger, Hidden Dragon	8	01:12–01:25
007	Anger mod.	Batman Returns	2	00:18–00:33
008	Anger mod.	Man of Galilee CD1	6	00:40–01:07
009	Anger mod.	The Untouchables	8	01:38–01:53
010	Anger mod.	Oliver Twist	15	02:05–02:25
011	Fear high	Batman Returns	5	00:09–00:25
012	Fear high	JFK	8	01:26–01:40
013	Fear high	JFK	8	00:08–00:25
014	Fear high	The Alien Trilogy	5	00:26–00:41
015	Fear high	Hannibal	1	00:40–00:54
016	Fear mod.	Running Scared	6	02:53–03:07
017	Fear mod.	The Untouchables	8	01:38–01:53
018	Fear mod.	The Fifth Element	17	00:00–00:19
019	Fear mod.	Lethal Weapon 3	7	00:00–00:16
020	Fear mod.	Man of Galilee CD1	2	03:45–04:02
021	Happy high	The Rainmaker	3	02:55–03:13
022	Happy high	Batman	18	00:55–01:15
023	Happy high	Shallow Grave	6	02:02–02:17
024	Happy high	Man of Galilee CD1	2	03:02–03:18
025	Happy high	Oliver Twist	1	00:17–00:34
026	Happy mod.	The Omen	9	00:00–00:24
027	Happy mod.	Oliver Twist	8	01:40–02:04
028	Happy mod.	Grizzly Man	1	00:00–00:27
029	Happy mod.	The Portrait of a Lady	3	00:23–00:45
030	Happy mod.	Nostradamus	2	01:09–01:28
031	Sad high	The English Patient	18	00:07–00:32
032	Sad high	Running Scared	15	02:06–02:27
033	Sad high	The Portrait of a Lady	9	00:00–00:22
034	Sad high	Big Fish	15	00:55–01:11
035	Sad high	Man of Galilee CD1	8	01:20–01:37
036	Sad mod.	Angel Heart	4	00:08–00:28
037	Sad mod.	Batman	5	01:08–01:22
038	Sad mod.	Dracula	7	00:00–00:12
039	Sad mod.	Shakespeare in Love	3	00:59–01:17
040	Sad mod.	The English Patient	7	00:00–00:31
041	Tender high	Shine	10	01:28–01:48
042	Tender high	Pride & Prejudice	1	00:10–00:26
043	Tender high	Dances with Wolves	4	01:31–01:48
044	Tender high	Pride & Prejudice	12	00:01–00:15
045	Tender high	Oliver Twist	8	00:14–00:30
046	Tender mod.	Batman	9	00:00–00:19
047	Tender mod.	Oliver Twist	8	01:15–01:32
048	Tender mod.	Dracula	4	00:55–01:09
049	Tender mod.	Juha	2	02:11–02:26
050	Tender mod.	Oliver Twist	2	00:00–00:29

(Continued)

Appendix. (Continued)

No.	Emotion & level	Album name	Track	Min:Sec
051	Valence pos. high	Juha	10	00:20–00:38
052	Valence pos. high	Blanc	12	00:51–01:06
053	Valence pos. high	Gladiator	17	00:14–00:27
054	Valence pos. high	Pride & Prejudice	9	00:01–00:21
055	Valence pos. high	Dances with Wolves	10	00:28–00:46
056	Valence pos. mod.	Man of Galilee CD1	2	00:19–00:42
057	Valence pos. mod.	Shakespeare in Love	21	00:03–00:21
058	Valence pos. mod.	Vertigo OST	6	02:02–02:17
059	Valence pos. mod.	Vertigo OST	6	04:42–04:57
060	Valence pos. mod.	Outbreak	6	00:16–00:31
061	Valence neg. mod.	Juha	18	02:30–02:46
062	Valence neg. mod.	Shakespeare in Love	11	00:21–00:36
063	Valence neg. mod.	Batman	9	00:57–01:16
064	Valence neg. mod.	The Fifth Element	9	00:00–00:18
065	Valence neg. mod.	Big Fish	15	00:15–00:30
066	Valence neg. high	The English Patient	8	01:35–01:57
067	Valence neg. high	Lethal Weapon 3	7	00:00–00:16
068	Valence neg. high	Road to Perdition	6	00:34–00:49
069	Valence neg. high	Hellraiser	5	00:00–00:15
070	Valence neg. high	Grizzly Man	16	01:05–01:32
071	Energy pos. high	The Untouchables	6	01:50–02:05
072	Energy pos. high	Man of Galilee CD1	2	03:02–03:18
073	Energy pos. high	Shine	5	02:00–02:16
074	Energy pos. high	Shine	15	01:00–01:19
075	Energy pos. high	Batman	18	00:55–01:15
076	Energy pos. mod.	Juha	2	00:07–00:18
077	Energy pos. mod.	Lethal Weapon 3	4	01:40–02:00
078	Energy pos. mod.	Crouching Tiger, Hidden Dragon	13	01:52–02:10
079	Energy pos. mod.	Batman	4	02:31–02:51
080	Energy pos. mod.	Oliver Twist	7	01:30–01:46
081	Energy neg. mod.	Juha	16	00:00–00:15
082	Energy neg. mod.	Big Fish	15	00:55–01:11
083	Energy neg. mod.	Big Fish	11	01:26–01:40
084	Energy neg. mod.	Blanc	18	00:00–00:16
085	Energy neg. mod.	Oliver Twist	6	00:51–01:07
086	Energy neg. high	Running Scared	15	02:06–02:27
087	Energy neg. high	Road to Perdition	16	00:17–00:32
088	Energy neg. high	Blanc	10	00:13–00:31
089	Energy neg. high	Blanc	16	00:00–00:15
090	Energy neg. high	Batman Returns	12	00:57–01:14
091	Tension pos. high	The Alien Trilogy	11	02:12–02:27
092	Tension pos. high	The Fifth Element	13	00:17–00:31
093	Tension pos. high	Babylon 5	3	02:47–03:00
094	Tension pos. high	Hellraiser	10	02:44–03:00
095	Tension pos. high	Oliver Twist	15	02:05–02:25
096	Tension pos. mod.	The Missing	3	02:45–03:06
097	Tension pos. mod.	Shallow Grave	4	01:04–01:19
098	Tension pos. mod.	Naked Lunch	7	01:01–01:20
099	Tension pos. mod.	Dracula	5	00:11–00:27
100	Tension pos. mod.	Cape Fear	2	01:25–01:40

(Continued)

Appendix. (Continued)

No.	Emotion & level	Album name	Track	Min:Sec
101	Tension neg. mod.	Juha	2	02:11–02:26
102	Tension neg. mod.	Shakespeare in Love	6	00:00–00:19
103	Tension neg. mod.	The Fifth Element	12	00:00–00:17
104	Tension neg. mod.	Crouching Tiger, Hidden Dragon	11	00:28–00:46
105	Tension neg. mod.	Pride & Prejudice	4	00:10–00:29
106	Tension neg. high	Lethal Weapon 3	10	01:59–02:17
107	Tension neg. high	The Godfather	5	01:12–01:28
108	Tension neg. high	Gladiator	4	00:48–01:06
109	Tension neg. high	Pride & Prejudice	13	01:02–01:20
110	Tension neg. high	Big Fish	8	00:12–00:34