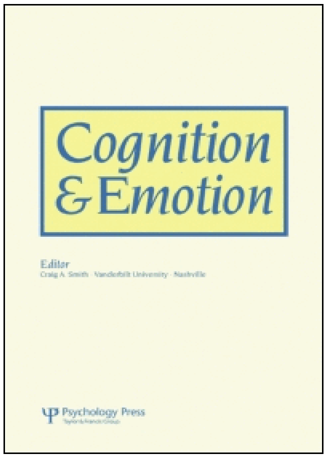

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Happy, sad, scary and peaceful musical excerpts for research on emotions

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Happy, sad, scary and peaceful musical excerpts for research on emotions

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Three experiments were conducted in order to validate 56 musical excerpts that conveyed four intended emotions (happiness, sadness, threat and peacefulness). In Experiment 1, the musical clips were rated in terms of how clearly the intended emotion was portrayed, and for valence and arousal. In Experiment 2, a gating paradigm was used to evaluate the course for emotion recognition. In Experiment 3, a dissimilarity judgement task and multidimensional scaling analysis were used to probe emotional content with no emotional labels. The results showed that emotions are easily recognised and discriminated on the basis of valence and arousal and with relative immediacy. Happy and sad excerpts were identified after the presentation of fewer than three musical events. With no labelling, emotion discrimination remained highly accurate and could be mapped on energetic and tense dimensions. The present study provides suitable musical material for research on emotions.

There has been increasing interest in the study of musical emotions since the publication of the first textbook on the topic (Juslin & Sloboda, 2001). A number of studies (Bigand, Vieillard, Madurell, Marozeau, & Dacquet,

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2005; Juslin & Laukka, 2003; Krumhansl, 1997; Peretz, Gagnon, & Bouchard, 1998) have demonstrated that musical emotions are not merely subjective experiences that are too variable to be studied scientifically. Rather, emotional responses to the music of one's culture appear to be highly consistent within and between listeners (Bigand et al., 2005; Juslin & Laukka, 2003), accurate (Juslin & Laukka, 2003), quite immediate (Peretz et al., 1998) and precocious (Cunningham & Sterling, 1988; Dalla Bella, Peretz, Rousseau, & Gosselin, 2001; Dolgin & Adelson, 1990; Kastner & Crowder, 1990; Terwogt & Van Grinsven, 1988).

Recently, Bigand and collaborators (2005) provided empirical support for the consistency of emotional responses to music in a test–retest situation in which musically trained and untrained listeners were required to group musical excerpts that conveyed similar emotions. The results revealed that groupings were highly consistent irrespectively of listeners' musical background and experimental session. A recent meta-analysis of 41 studies of music performance that expressed typical emotions, revealed that happiness, sadness, anger, threat and tenderness were decoded with above-chance accuracy by listeners (Juslin & Laukka, 2003). Regarding immediacy, Peretz and collaborators (1998) showed for the first time that non-musician listeners were able to distinguish happy from sad music within as little as half a second from the beginning of the music. As mentioned above, emotional processing of music emerges early in development. From 2 to 4 months old, infants exhibit a preference for consonant-pleasant over dissonant-unpleasant music (Trainor, Tsang, & Cheung, 2002). At the age of three, children can discern happy from sad tones in music of their own culture (Kastner & Crowder, 1990). At four, children explicitly recognise happiness (Cunningham & Sterling, 1988), and by the age of six, they identify sadness, threat and anger in music (Dolgin & Adelson, 1990; Terwogt & Van Grinsven, 1988). These studies typically report better performance in recognising happiness, while threat and anger are often confounded. Taken together, these findings suggest that emotional associations to music are established relatively early in development. Furthermore, at five years of age, children discriminate happy from sad music by relying on tempo differences (fast versus slow) while at six, they are able to perform discrimination by using mode changes (major versus minor) as do adult listeners (Dalla Bella et al., 2001). The fact that such emotional responses appear so early in development suggests that emotions are an integral part of musical experience.

Neuroimaging studies point to the involvement of cerebral structures that are distinct from those involved in music perception (Blood, Zatorre, Bermudez, & Evans, 1999; Koelsch, Fritz, v Cramon, Müller, & Friederici, 2006). Intense emotional responses, eliciting chills in the music listeners, activate brain regions that are implicated in reward and motivation (Blood & Zatorre, 2001). The amygdala has also been recently identified as playing a critical role in the recognition of threatening or scary music (Gosselin, Peretz, Johnsen, & Adolphs, 2007; Gosselin et al., 2005). Gosselin et al. (2006) furthered the specification of the neural basis of emotional responses by showing that the parahippocampal cortex is a critical brain area involved in judging dissonant music as unpleasant.

Despite the increasing interest in musical emotions, many questions remain. We still do not fully understand how music evokes emotions, and why music is such a powerful means to elicit emotions. As a first step, a clear set of emotional stimuli needs to be established. In contrast to the standard stimuli used in the testing of facial expressions (Ekman & Friesen, 1976) and visual scenes (Lang, Bradley, & Cuthbert, 1998), there is currently no standard set of musical excerpts that exists. The Ekman's face series consists of 110 pictures of facial expressions of young Caucasian adults that portray happiness, sadness, surprise, fear, and disgust (Ekman & Friesen, 1976). The International Affective Picture System (IAPS) of Lang and collaborators (1998) includes 60 different coloured photographs that vary in terms of valence and arousal, and represent a wide range of semantic categories. Both Ekman and Lang's series are currently used for experimental investigation on a wide range of topics such as emotional decoding (Balconi, 2005; Matsumoto & Ekman, 2004; Rossignol, Philippot, Douilliez, Crommelinck, & Campanella, 2005), emotion and decision making (Beer, Knight, & D'Esposito, 2006), normal and pathological ageing (Biseul et al., 2005; Mather & Knight, 2005), neuropsychology (Allerdings & Alfano, 2006; Garcia-Caballero, Gonzalez-Hermida, Garcia-Lado, & Recimil, 2006), psychopathology (Campanella, Vanhoolandt, & Philippot, 2005; Neumann, Blairy, Lecompte & Philippot, 2007) and neuroimaging (Bermpohl et al., 2006; Britton, Taylor, Sudheimer, & Liberzonb, 2006; Moriguchi et al., 2005). This illustrates the importance of a validated set of stimuli for research on emotion. However, these stimuli are limited to the visual modality.

To our knowledge, there is as yet no available set of musical stimuli for research on emotion. The main goal of the present study is to provide such a stimuli set.

We selected four emotion categories—happiness, sadness, threat and peacefulness—that can be distinguished on the dimensions of valence and arousal. These choices were motivated by the two main approaches in emotion research: a categorical approach, which views emotions as triggering basic and distinct adaptive behaviours, and a dimensional approach, which characterises emotions along two or three main dimensions. In the categorical approach, basic emotions correspond to a limited number of innate and universal emotion categories (happiness, sadness, anger, fear and disgust) from which all other emotions can be derived (Ekman, 1982; Izard, 1997). Support for this approach can be found in neuropsychological and functional brain imaging studies. For example, recognition of facial expressions of fear may be linked to specific neural substrates such as the amygdala (Adolphs, Tranel, Damasio, & Damasio, 1994; Calder et al., 1996; Morris et al., 1996; Phillips et al., 1998), and the recognition of facial expression of disgust may be related to the basal ganglia and the anterior insula (Gray, Young, Barker, Curtis, & Gibson, 1997; Phillips et al., 1998; Sprengelmeyer et al., 1996). The dimensional approach considers that emotions are organised along fewer psychological dimensions. For example, the Russell's affect circumplex model (Russell, 1980) contains two main affective dimensions reflecting degrees of valence and arousal, and two secondary axes at 45° corresponding to excitement and distress.

Support for Russell's model in the musical domain has been provided by Wedin (1972). In that study, musical excerpts belonging to various musical styles (e.g., classical, jazz, popular) were judged in terms of emotionally coloured adjectives (e.g., relaxed, furious, dark, vigorous) using multi-dimensional scaling analysis. Three dimensions were extracted and labelled Intensity–Softness, Pleasantness–Unpleasantness, and Solemnity–Triviality. Similarly, in a more recent study (Bigand et al., 2005), a three-dimensional account was found to explain the emotional groupings of listeners on musical excerpts with arousal and valence as the primary dimensions. Thus, our set of musical excerpts allowed us to use both a categorical approach and a dimensional approach.

The present set of stimuli was composed in the genre of film music so as to express happiness, sadness, threat and peacefulness. In Ekman's classification, happiness, sadness and fear/threat are considered as basic emotions and are well studied. Peacefulness is not a basic emotion. It was added here so as to contrast with threat, mirroring the fact that happiness is the opposite of sadness. Furthermore, in Ekman's classification, fear instead of threat is considered basic. However, fear is an ambiguous label for music. It may refer either to the emotional state of the *imagined* performer or to the feeling of the listener. A performer may express fear by playing softly, for example, or may wish to induce fear in the listener by playing loudly. Moreover, the music that will evoke fear in the listeners may not motivate a fight or flight response. Rather musical signals of danger are usually more diffuse. This is why we use threat and scary as labels to refer to the intended emotions in the present set of stimuli.

In music, happiness, sadness, threat and peacefulness define a space along valence and arousal. Happy excerpts, with a fast tempo in a major mode should be rated as arousing and pleasant. Sad excerpts, with a slow tempo in minor mode, should be judged as low in arousal. Given that sadness may elicit a melancholic feeling, it might be judged as somewhat pleasant. Threatening excerpts, expressed in a minor mode with intermediate tempo, should be rated as arousing and unpleasant. Finally, peaceful excerpts characterised by a slow tempo and major mode should be perceived as little arousing and pleasant.

In this study, we focus on the musical structure (e.g., mode, dissonance), and less on the manner in which the musical performance conveys different expressive properties (e.g., dynamics, attacks). Our intent was to compose excerpts that convey emotions by virtue of their musical structure and not their musical expressivity. Although tempo can be defined as a means of expressivity, we considered it to be a structural determinant whereby tempo can be specified in musical notation. The musical material consists of 56 excerpts with 14 stimuli per emotion category, labelled as happiness, sadness, threat and peacefulness.[1] Excerpts were composed following the rules of the Western tonal system and are based on a melody with an accompaniment. All excerpts were computer-generated and recorded in a piano timbre.

We were interested in the emotional responses of the ordinary listener, the target of most studies on emotions. Accordingly, participants were non-musicians, except in the first experiment in which listeners were recruited regardless of their musical training. In the first experiment, emotional categorisation, as well as valence and arousal judgements were examined. In the second experiment, the time course of the emotional responses was tested by using a gating paradigm. The main goal was to determine the number of musical events that are necessary for accurate recognition so as to obtain an optimal duration for the musical stimuli. In the third experiment, emotional recognition was studied without labelling to avoid potential bias introduced by verbal descriptors. To this aim, listeners were asked to decide to what extent pairs of excerpts were emotionally dissimilar. A multidimensional scaling method (MDS) was applied to specify the structure of judgements and to extract determinants of emotional responses.

EXPERIMENT 1: CATEGORISATION, VALENCE AND AROUSAL

Method

Participants. Fifty-nine right-handed students (23 men and 36 women), between 18 and 48 years of age (mean: 23), coming from Montreal and Sherbrooke universities, performed one of two rating tasks. They were recruited without regard to musical training. Thirty-two had no musical

[1] Ekman and Friesen's (1976) affective pictures and collaborators comprises 14 different stimuli for each category of emotion.

training. The others declared having some degree of training (from 1 year of guitar playing to 8 years of piano lessons). All subjects were paid for their participation.

Material. The happy excerpts were written in a major mode at an average tempo of 137 Metronome Marking (MM range: 92–196), with the melodic line lying in the medium–high pitch range (the pedal was not used). The sad excerpts were written in a minor mode at an average slow tempo of 46 MM (range: 40–60), with the pedal. The peaceful excerpts were composed in a major mode, had an intermediate tempo (mean: 74, range: 54–100), and were played with pedal and arpeggio accompaniment. The scary excerpts were composed with minor chords on the third and sixth degree, hence implying the use of many out-of-key notes. Although most scary excerpts were regular and consonant, a few had irregular rhythms (e.g., P04) and were dissonant (e.g., P06; see Appendices 1 and 2). Tempo varied from 44 to 172 MM. The stimuli durations were of 12.4 s (range: 9.2–16.4) and were matched in length across the four emotional categories. Examples can be heard at www.brams.umontreal.ca/peretz.[2]

Apparatus. The excerpts were generated on a microcomputer as musical instrument digital interface (MIDI) files using Sequencer Plus Gold software. Each tone occupied its precise value in terms of pitch and duration, with constant intensity and velocity. The MIDI files were output to a sample playback digital synthesiser (Rolland Sound Canevas SC 50) set to piano timbre and digitally recorded on to compact disks.

Procedure. The set of 56 stimuli, preceded by two examples, was copied on two CDs in different random orders, with 6 seconds of silence between excerpts. The two examples were short excerpts of the familiar soundtracks of the films *Jaws* and *Schindler's List* and served as examples for threatening and sad music, respectively.

Two groups of listeners were defined based on the type of ratings they were requested to provide. For each type of rating, there were two groups of listeners allocated either to one presentation order or to the other. Each excerpt was presented only once. In the categorisation task, twenty listeners judged to what extent they *recognised* each of the four emotions labelled as "gai" (happy), "triste" (sad), "épeurant" (scary) or "apaisant" (peaceful) in each excerpt, while the other 19 listeners judged to what extent they *experienced* each of these emotions. For each labelled emotion, listeners performed a rating on a 10-point scale, where 0 indicated "*absent*" and 9

[2] The full set of excerpts can be obtained from the corresponding author upon request.

"*present*". Listeners had been previously informed that they had to provide a rating for the four emotion labels.

A third group of 20 participants performed the valence and arousal judgements. They rated on a 10-point scale whether each excerpt sounded unpleasant or pleasant (with 0 meaning "*désagréable*"/unpleasant and 9 meaning, "*agréable*"/pleasant) and whether each excerpt was relaxing or stimulating on another scale (with 0 corresponding "*relaxant*"/relaxing and 9 to "*stimulant*"/stimulating).

The testing session lasted about 30 minutes. Participants were tested in groups of three, four or five.

Results

Categorisation task[3]. Since subjects were free to choose as many of the four emotional labels (happy, sad, scary and peaceful) as they wished to provide a graded judgement for each, we first assessed whether the stimuli elicited specific, mixed or undifferentiated emotions. Following the procedure proposed by Mikels and collaborators (2005), we computed the means for the four ratings for each musical stimulus individually. A 90% confidence interval (CI) was constructed around each mean, and category membership was determined according to the overlap of the CIs for each rating. For a given musical excerpt, if the mean for one emotion label was higher than the means of all the other three emotion labels and if the CI for that emotion did not overlap with the CIs for the other three emotion categories, it was classified as specific. If two of three means were higher than the others, and if the CIs of those means overlapped with each other, then the musical excerpt was classified as eliciting blended emotions.

This analysis revealed that all musical stimuli elicited specific emotions. Even for a musical excerpt (such as A14 in Appendix 2) whose emotional intention was poorly recognised by the participants (with 51% of correct matches), its mean rating of 5.3 (CI: 4.5–6.1) for the intended peaceful emotion was much higher than for the other labels (with 2.0, 2.8 and 0.5) and its confidence interval did not overlap with the CI of the other emotions (CI: 1.4–2.7, 2.0–3.5, 0.1–0.8). Therefore, as done in our previous studies (Gosselin et al., 2005, 2006), we derived the *best label* attributed to each musical excerpt by each participant. This was done by selecting the label that had received the maximal rating. When the maximal rating corresponded to the label that matched the intended emotion, a score of 1 was given. When the maximal rating did not correspond to the emotion, a score of 0 was

[3] The data of one subject allocated to the emotion experience instruction were rejected because of the high number of missing responses. Analyses were thus performed on a sample of 39 listeners.

given. When the highest rating was given for more than one label, the response was considered as ambivalent and received a score of 0. For instance, when an excerpt was judged to express both peacefulness and sadness to the same degree (e.g., with a rating of 7), it was considered ambivalent. Note that ambivalent judgements do not correspond to the blended emotions described above. One stimulus may elicit an ambivalent judgement in one participant and not in another one, whereas blended emotions must be judged as such by a majority of participants. These scores are presented in Table 1.

The effect of instructions of emotion *recognition* versus *experience* was tested by performing a mixed analysis of variance (ANOVA) with the Mean Best Label for the four intended emotions as within-subjects factor, and the Instruction Condition (recognition vs. experience) as the between-subjects factor. A significant effect of Instruction, $F(1, 37) = 4.97$; $p = .032$; $\eta^2 = .118$, was observed, with a higher rating for the intended emotion in the experience condition (from .82 to .91 across emotional categories) than in the recognition condition (from .76 to .84 across emotional categories). No significant interaction was found between the instructions and emotion categories. Further independent sample *t*-test comparisons between recognition and experience instructions were performed for each emotion. Subjects who paid attention to their emotional experience gave a significantly higher rating for the "sad" label (from .82 to .97) than those allocated to the emotion recognition instruction (from .73 to .87). Since this difference was a general and relatively small effect, the data were averaged across the type of instructions in the following analyses.

As shown in Table 1, the intended emotion was recognised with more than 80% correct for happiness, sadness and threat. Happiness was best recognised (with 99%), while the peaceful excerpts were less well recognised with a score of 67%. Peacefulness tended to be more often equivocal with

TABLE 1

Mean percentage of the label that received the maximal rating by the 39 listeners as a function of the intended emotion of the composer. Bold indicates the match between responses and intended emotions. Ambivalent responses correspond to highest ratings given to more than one label

	Response				
Intention	*Happy*	*Sad*	*Threat*	*Peaceful*	*Ambivalent*
Happy	**99**	0	0	0	1
Sad	0	**84**	1	7	8
Scary	5	8	**82**	0	5
Peaceful	8	12	1	**67**	12

12% of ambivalent responses that are mostly due (75%) to confusion with sadness.

Valence-arousal. For each excerpt, the mean rating of valence and arousal were computed. These are plotted in Figure 1. As can be seen, subjects systematically rated the happy and peaceful music as pleasant and the scary excerpts as unpleasant. The sad excerpts are located on the pleasant part of the valence dimension. Along the arousal dimension, the sad and peaceful excerpts received a relatively low rating, while the scary and happy music received a rather high rating. The ANOVA performed on the mean ratings for each excerpt as a Function of Emotion Category as the between-items factor, and as a Function of Valence and Arousal as a within-items factor yielded a significant interaction between dimensions, with $F(3, 52) = 359.83$, $p < .001$; $\eta^2 = .954$. Post hoc Tukey tests confirmed that peaceful and sad excerpts differed from each other ($p < .001$), despite their close proximity. Similarly, the ANOVA performed on the mean ratings for each Emotion Category as a function of Valence and Arousal as the within-subject factor revealed a significant interaction between the Emotion Category and the Type of Rating, with $F(3, 57) = 140.50$, $p < .001$; $\eta^2 = .846$.

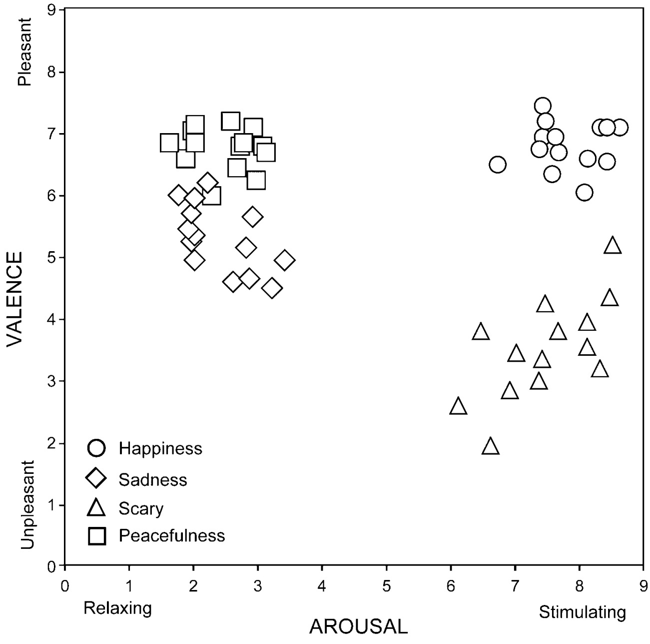

Figure 1. Mean rating on a 10-points scale obtained for each excerpt on valence and arousal. Each symbol represents one musical excerpt.

Again, the post hoc Tukey tests indicated that judgements for peaceful and sad excerpts significantly differed from each other ($p < .05$).

The relation between the valence and arousal ratings was assessed by Pearson correlations between the mean scores given for each excerpt on both dimensions. There was no significant correlation ($r = -.24$ with 54 *df*), indicating that valence and arousal judgements were unrelated.

Given that musical tempo is a continuous dimension (contrary to musical mode, which is binary), this musical parameter was used as predictor in a linear regression model of arousal ratings across all categories. A statistically significant effect, $F(1, 54) = 69.14$; $p < .001$, was observed with an R^2 value of .561, indicating that the faster the tempo, the more stimulating the musical excerpt was judged.

Discussion

The recognition of the intended emotion from the present set of musical stimuli was little affected by instructions. In general, musical excerpts were slightly better recognised, especially sadness, when subjects focused on their emotional experience than when they were merely asked to recognise the emotional content, suggesting that personal engagement may facilitate emotion recognition. These findings are compatible with the idea that the relationship between emotion recognition and emotion experience is a matter of degree, not in kind. More importantly, the results indicate that musical excerpts succeed in conveying and, for some, potentially inducing a congruent affective state.

In the categorisation task, the results show that decoding accuracy of all four emotions (happiness, sadness, threat and peacefulness) is higher than what would be expected by chance level (which corresponds to 25% in a four-choice recognition task). The valence-arousal judgements confirm the fine emotional discrimination along the two main dimensions of emotional response to music. Recently, the same musical material was used to explore how patients with amygdala resection and their controls recognised emotion in music (Gosselin et al., 2005). In controls,[4] the mean best labels were 91%, 53%, 86% and 70% for happy, sad, scary and peaceful excerpts. This is similar to the present data (with 99%, 84%, 82%, and 67%, respectively), except for the sad excerpts, which were better recognised here. In addition, there was an unequivocal discrimination between low- and high-arousing excerpts. Altogether, the results are fairly consistent across populations who

[4] In Gosselin et al.'s (2005) study, normal controls were selected to match the patients as closely as possible in terms of age (ranged from 27 to 47), sex (7 male, 9 female), education (ranged from 9 to 19 years) and musical background (ranged from 0 to 5 years of musical education). Thus, the characteristics of these subjects differ somewhat from the rather homogeneous pool of students tested here.

differ in age and education. Moreover, the results replicate prior data showing that happiness is the easiest emotion to recognise from music (Juslin & Laukka, 2003). This provides evidence for emotional recognition consistency across participants and tasks.

EXPERIMENT 2: GATING TASK

Another method for probing emotional processing is to use dissimilarity judgements as used by Bigand and collaborators (2005). Since this task requires multiple presentations of the same stimuli and because our stimuli were rather lengthy (13 s on average), we used here a gating paradigm to determine the shortest duration that can lead to reliable emotional recognition.

Peretz et al. (1998) showed that 250 ms from the beginning of a musical excerpt are sufficient to distinguish happy from sad music. Recently, Bigand et al. (2005) showed that responses to a large variety of emotions were consistent when excerpts were presented for 1 s. However, these studies did not take into account the fact that the number of musical events varies as a function of the emotion conveyed. That is, the number of events in a slow sad music excerpt is smaller than in a fast happy one. This difference in terms of number of events may serve as a cue for emotional recognition. Here, we controlled for this factor by defining each gate by the number of events presented and not its duration.

The gating task consisted of presenting increasing gates of music. Here a gate corresponded to one note or one chord as used in Dalla Bella, Peretz, and Aronoff (2003). After each gate, listeners were asked to select an emotion label in a forced-choice task. The number of gates (or events) required for emotional recognition was measured, taking into account *correct* and *confident* recognition. *Correct* recognition is the number of gates *during* which the listener maintains the same emotional label. *Confident* recognition refers to the number of gates *until* the selection of the intended emotion is selected with a maximum confidence level on three successive trials. *Confident* recognition scores served to establish the optimal duration of stimuli to be used in Experiment 3.

Method

Participants. Ten right-handed students (8 women), aged 20–25 years, from the University of Montreal participated in the experiment, and were randomly assigned to one of two orders of stimuli presentation.

Material and procedure. The duration of the 56 excerpts was reduced from 12.4 s to 5 s on average according to a pilot study that indicated that 5 s was sufficient to reach a reliable decision. The number of events (i.e., gates) varied from 10 to 39 for the happy excerpts; from 7 to 17 for the sad excerpts; from 6 to 44 for the scary excerpts and from 9 to 20 for the peaceful excerpts. Each excerpt was segmented event-by-event except for the first segment, which always contained the first two events. After each gate, listeners were asked to recognise the emotion by choosing *only one label* from happiness ("gai"), sadness ("triste"), threat ("épeurant") and peacefulness ("apaisant"), and to rate their confidence on a 7-point scale, with 1 corresponding to *uncertain* ("*incertain*"), and 7 to *very certain* ("*vraiment certain*"). This procedure was repeated after each increasing segment and the gated presentation lasted until the listeners had chosen three successive consistent choices with a maximum confidence rating of 7. Two examples of the gated presentation drawn from a familiar movie soundtrack (i.e., *Jaws* and *Schindler's List*) preceded the testing phase. Each subject performed two sessions of 45 minutes each, separated by a short break.

Results and comments

Correct recognition. The mean percentages of correct recognition were very high with 95%, 86%, 71% and 91% for happy, sad, scary and peaceful excerpts, respectively. These scores were compared to those obtained in Experiment 1 with an ANOVA considering Emotional Categories as the within-subjects factor and Experiment as the between-subjects factor. The analysis revealed an interaction between Emotion and Experiment, $F(3, 78) = 10.33$; $p < .001$. Post hoc Bonferroni test comparisons indicated that peacefulness was better recognised here in the gating task (91%) than in Experiment 1 (67%). No other significant difference was found.

The mean number of musical events required for the correct recognition of the four emotions is displayed in Figure 2. Happy and sad excerpts required very few events, with 2.8 on average, to be recognised whereas the scary and peaceful music required 5 and 4 events on average. An ANOVA performed on the Mean Number of Musical Events required for correct recognition of each emotion as the within-subjects factor yielded a significant effect of emotion, $F(3, 27) = 13$; $p < .001$. Further pairwise mean comparisons showed that the scary excerpts took longer to be recognised than the other excerpts (all ps $< .05$) and that happiness was significantly more immediate than peacefulness ($p < .05$).

The mean number of musical events was translated in terms of mean duration for each emotion category. It takes 483 ms, 1446 ms, 1737 ms and 1261 ms on average for the correct recognition of the happy, sad, scary and peaceful excerpts, respectively. A repeated ANOVA performed on duration of each excerpt with Emotion Category as the within-subjects factor showed a significant main effect of Emotion Category, $F(3, 39) = 7.01$; $p < .001$. Post

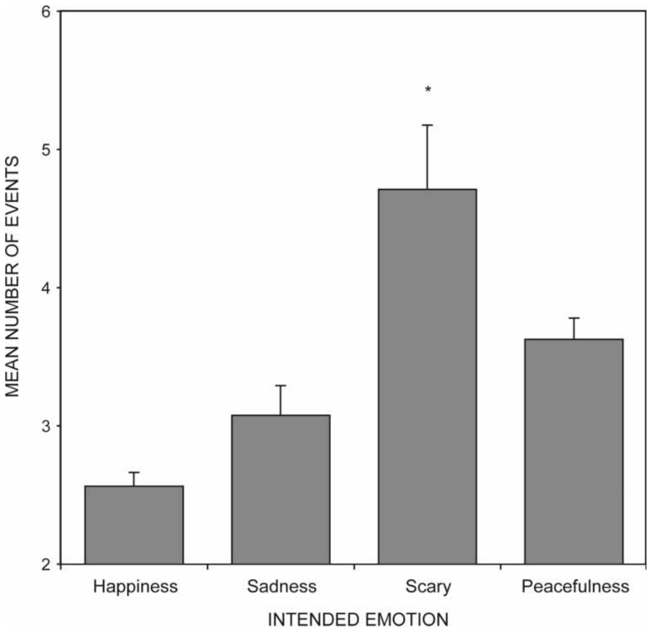

Figure 2. Mean number and standard error of events required for the recognition of the intended emotion. *Note*: $*p < .05$

hoc comparisons indicated that happy excerpts differed from scary ($p < .001$) and sad ($p < .05$) excerpts.

Since the scary music was found to be more difficult to recognise, the nature of the errors was examined. Fifty-five percent of the errors were due to confusion with the "happy" emotion, and 38% to the "sad" one (the remaining 7% corresponded to peacefulness). Three stimuli (P06, P08 and P13) were the main source of these errors (ranging from 50 to 90%). Excerpts P06 and P08 were confounded with happiness, and P13 was categorised as sad music. These ambiguous excerpts were discarded in Experiment 3. Since the scary excerpts had varying degrees of dissonance and irregularity, we examined whether these structural features could have influenced the listeners' choice. Musical dissonance, unexpectedness and irregularity were rated by a professional musician so as to provide a portrayal for each threatening excerpt (Appendix 1). Tempo was also taken into account. Using a linear multiple regression analysis with musical features (dissonance, unexpectedness, irregularity and tempo) as predictors, no specific contribution of these factors could be found on recognition performance.

Confident recognition. Confident recognition refers to the number of gates that are necessary to reach a maximal confidence level of 7 on three successive trials. These ratings were associated with 95%, 78%, 71% and 89% correct recognition of the happy, sad, scary and peaceful excerpts, respectively. The mean number of musical events required for confident recognition shows that listeners need an average 7 events for the happy and sad excerpts, 8 for the peaceful and 9 for the scary excerpts. In terms of duration, listeners take an average of 1096 ms, 3999 ms, 3152 ms and 2884 ms to confidently recognise happy, sad, scary and peaceful excerpts, respectively.

Interestingly, recognition accuracy does not improve with increasing confidence, suggesting that first intuitions are generally correct. At any rate, confident recognition provided the optimal durations that were used in the third experiment, which required the comparison of two excerpts.

To summarise, happy and sad music were more rapidly recognised than scary and peaceful music. The observation that scary music is not immediately recognised supports the idea that music may signal danger in a more diffuse manner than in most other domains. In the visual domain, for example, fear-relevant stimuli (e.g., a snake) typically drive attention (e.g., Öhman, Flykt, & Esteves, 2001). That is, fear-relevant pictures are detected more quickly than fear-irrelevant ones. Perhaps scary music takes longer to be recognised because there is no obvious evolutionary advantage attached to its immediacy.

EXPERIMENT 3: DISSIMILARITY JUDGEMENTS

The dissimilarity judgement task consisted in asking subjects to assess the extent to which two musical excerpts were dissimilar in the emotion they conveyed. The task did not use verbal labels. The dissimilarity judgements were then displayed on a geometrical space obtained with multidimensional scaling analysis (MDS), which transformed dissimilarities in geometrical distances into an *n*-dimensions solution. The solutions represent the structure of the emotional judgements and the dimensions that characterized those judgements.

Recently, a dissimilarity judgements task was used to study the emotional judgements of listeners when presented with musical excerpts of various emotional contents (Bigand et al., 2005). Participants performed emotional dissimilarity judgements on 351 pairs of 1 s duration excerpts. Multidimensional scaling analysis revealed a 3-dimensional space with arousal and valence as the primary dimensions. The third dimension, contrasting musical pieces with different melodic gestures was interpreted as a kinetic component. Similarly here, we expected that the MDS solution would reflect four categories of excerpts located in emotional space in terms of valence and arousal.

Method

Participants. Sixteen right-handed students (12 women) between 20 and 26 years of age, from the University of Montreal, participated in the experiment. They had no formal musical training and had never been exposed to the excerpts before; they were paid for their participation. Data from one subject were eliminated due to technical problem with the program. Analyses were thus performed on the responses of 15 listeners.

Material and procedure. Of the 56 excerpts tested in Experiment 2, sixteen excerpts were discarded because the mean percentage of the maximum confidence level was low. The emotions of the forty remaining excerpts were confidently recognised with 99%, 84%, 72%, and 94% correct for happiness, sadness, threat and peacefulness, respectively. Accordingly, there were 10 musical excerpts per emotion category (Appendix 2). The mean duration and the mean number of events were 1.1 s and 6 events for happiness, 3.5 s and 6 events for sadness, 3.3 s and 7 events for threat and 2.9 s and 7 events for peacefulness. A 40×40 matrix was constructed with these stimuli and each possible pair of excerpts was created, except for the same stimuli, which were never paired together. There were 780 pairs of excerpts presented in two possible orders (pair AB vs. BA).

Stimuli were recorded as mono files at 16 bits and 44 KHz, and the overall loudness was normalised. These were presented over Professional Beyer Dynamic DT 770 headphone. Eprime software (2000) was used for stimuli presentation and response recordings.

On each trial, a pair of excerpts separated by 800 ms was presented over the headphones. Participants were asked to judge to what extent the emotions expressed by the two excerpts were dissimilar on a continuous rating scale presented on the screen, going from "*pas du tout différent*" ("*not different at all*"), to "*tout à fait différent*" ("*completely different*"). Two seconds after the rating, the next trial was automatically presented.

The task was divided into 3 sessions over three days within one week. Each session lasted about 40 minutes. Participants were randomly assigned to one of the two order presentations. At the beginning of the first session, all excerpts were presented once to familiarise the subjects with the musical material.

Results

For each pair of excerpts, the dissimilarity judgement was measured in terms of cursor location, which ranged from 153 to 829 dots (corresponding to the number of pixels in the rating scale). The 780 dissimilarity judgements obtained from each listener were converted into a 40×40 symmetric matrix in which each cell indicated the emotional dissimilarity between two excerpts. A high value meant that the two corresponding excerpts were perceived as conveying very different emotions.

Since pairs of excerpts were presented in two possible orders (AB vs. BA), the reliability of dissimilarity judgements could be assessed by computing Pearson correlations between the mean ratings given by the two subgroups assigned to one of the two presentation orders. The correlation value $r(778) = .87$ ($p < .001$), suggests a high agreement between groups.

The multidimensional scaling analysis was performed with 15 rectangular (symmetric) individual matrices of dissimilarities. Each of them was compiled and computed by a PROXSCAL MDS algorithm in the SPSS software (Kinnear & Gray, 1999). The analysis gave a two-dimensional solution in a common geometrical space using the Torgerson classical metric analysis. We applied a generalised Euclidean model including weighted common dimensions as function of each individual matrix. The badness-of-fit measure for the MDS solution, represented by the normalised Stress value is .09. This implies that more than 99% of the distances between the points located in the geometrical solution match the rank order of the dissimilarities in the proximity matrix. The percentage of variance accounted for by the solution reaches 91%. Altogether, these indexes indicate that the 2-dimensional Euclidean model gives a good fit to the dissimilarity values. Since the addition of a third dimension to the model did not increase the fit, the 2-dimensional solution was retained. The location of the 40 excerpts along the two dimensions is represented in Figure 3.

As it can be seen in Figure 3, the space is clearly divided into four categories including happiness, sadness, threat and peacefulness. The first dimension distinguishes the sad from the happy excerpts, while the second dimension distinguishes the peaceful from the scary excerpts.

Correlation analyses were performed to test for associations between the mean co-ordinates of each excerpt on dimensions 1 and 2 (obtained with MDS) and the valence and arousal ratings collected in Experiment 1, on the one hand, and the musical tempo, on the other. Spearman's correlation matrix indicated that dimensions 1 and 2 positively correlated with arousal ratings, with $r(38) = .79$, $p < .001$ and $r(38) = .41$, $p < .001$, respectively. Moreover, valence ratings positively and moderately correlated with dimension 1, $r(38) = .39$, $p < .05$, whereas it negatively and highly correlated with dimension 2, $r(38) = -.77$, $p < .001$. Finally, tempo was highly and positively correlated with dimension 1, $r(38) = .87$, $p < .001$, but not with dimension 2, $r(38) = .06$. As discussed later, this pattern of correlations cannot be easily interpreted in terms of two orthogonal arousal/valence dimensions.

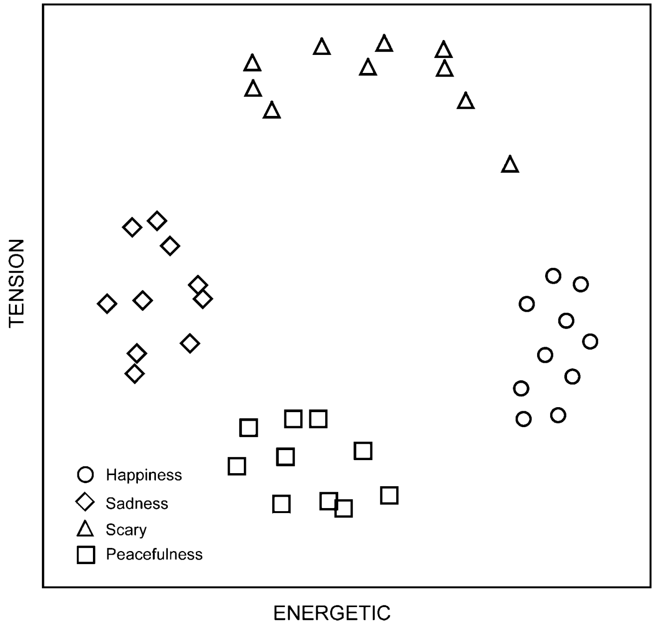

Figure 3. Geometrical solution for 40 stimuli resulting from multidimensional scaling of emotional dissimilarity judgement data

Discussion

With no emotional labels and relatively short musical excerpts, listeners succeeded in distinguishing each excerpt as pertaining to one of the four emotion categories. This corroborates previous data demonstrating that no emotional descriptor is needed for accurate emotional recognition (Bigand et al., 2005). Unlike this prior study, the dissimilarity judgements did not fit with a valence–arousal two-dimension space. Rather, the two-dimensions solution of the MDS structure are more consistent with the energetic and tension dimensions underlying the emotional judgement of music.

Indeed, the solution fits with a positive activation/negative activation model (Watson, Wiese, Vaidya, & Tellegen, 1999) and an energetic and tense-arousal model (Thayer, 1986, 1989, 1996), both of which models incorporate two dimensions characterised by a combination of activation/pleasantness dimension. More specifically, dimension 1 in the MDS solution contrasts sad music, which is moderately pleasant and slow, with very pleasant happy music, which conveys energy. Dimension 2 contrasts pleasant peaceful music to unpleasant high-arousing music. Thus, the first axis may be interpreted as an energetic dimension. The second axis may reflect tension.

To test the psychological validity of this interpretation, a control group of 13 musically untrained subjects from the University of Toulouse were asked to judge energy and tension as descriptors of the set of 40 excerpts on two 10-point scales varying from 0 "*pas du tout*" (*not at all*) to 9 "*tout à fait*" (*completely*). Participants rated to what extent musical excerpts were energetic, in eliciting the desire to move, on one scale. On the other scale, they judged to what extent music communicated tension. The average ratings are presented in Table 2. The energy ratings highly correlated with dimension 1, with $r(38) = .92$, $p < .001$, whereas these did not correlate with dimension 2, $r(38) = -.01$. Conversely, the tension ratings correlated with dimension 2, with $r(48) = .90$, $p < .001$, while these did not correlate with dimension 1, $r(38) = .20$.

Several factors may account for the discrepancy obtained between the present MDS solution and that of Bigand et al. (2005). One factor may be related to axes rotation. As shown in self-reported affects (Feldman Barrett & Russell, 1998; Russell & Feldman Barrett, 1999; Yik et al., 1999), differences in the interpretation of dimensions may be a question of 45° rotation. Moreover, we did not use the same set of musical stimuli. The present excerpts were composed with the intention of using similar musical structure to convey typical emotions. These clear emotional intentions probably helped listeners to contrast emotions that appear as natural antagonists (e.g., happy/sad; peaceful/threat). In Bigand et al.'s (2005) study, excerpts were taken from the classical music repertoire with the purpose of evoking a variety of emotions. This diversity may promote an organisation in terms of valence and arousal dimensions that represents the most salient cues across the musical excerpts. Finally, the two studies did not apply the same MDS model of analysis. Bigand et al. (2005) used a classical EXSCAL MDS (Winsberg & Carroll, 1989), which transforms the average matrix of dissimilarities in geometrical distance without taking into account individual matrices. Here, we applied a PROXSCAL MDS analysis, which provides weight for each individual matrix. Such a solution, that is not invariant to rotation, takes interindividual

TABLE 2
Mean rating and standard deviation on energy and tension for each intended emotion

	Ratings	
Intended emotion	*Energy*	*Tension*
Happy	6.8 (0.6)	3.4 (0.5)
Sad	1.9 (0.5)	3.2 (0.6)
Scary	3.9 (2.1)	6.1 (0.7)
Peaceful	2.9 (0.7)	2.6 (0.6)

variability into account so as to optimise the representation of emotional judgements.

Finally, it is worth pointing out that the clear-cut solution obtained here with dissimilarity judgements and no emotion labels could be related to the structural features purposely used to create the stimuli. Support for the idea comes from the high correlation found between tempo and the energetic dimension 1, which also corresponds to the musical excerpts (sad–happy) that were the most distinctive in terms of tempo. Thus, the energetic-tension solution offered here remains a hypothesis for further testing.

GENERAL DISCUSSION AND CONCLUSION

The present study investigated the listeners' ability to recognise four distinct emotions (happiness, sadness, threat, peacefulness) in musical excerpts that were composed to purposely convey these emotions. Three experiments were conducted to probe recognition accuracy and immediacy with different methods. In Experiment 1, the musical excerpts were found to convey the intended emotions with little ambiguity and to be easily discriminated along the relaxing–stimulating and the pleasant–unpleasant dimensions. In Experiment 2, the time course analysis of recognition highlighted the immediacy of happiness and sadness recognition. In Experiment 3, dissimilarity judgements were best explained by a two-dimension space defined along an energetic and a tension dimension.

Happiness is the most accurately and quickly recognised emotion among the four tested categories. This is a recurrent finding in the domain of face processing and can be explained by the fact that the smile is a highly distinctive facial feature and that happiness is the only positive emotion typically represented. In the present musical material, however, happy music is not the only positive emotion. Peacefulness and sadness to some extent are perceived as pleasant by the participants. Thus, it might be that happy stimuli are promptly recognised because these represent a preferential bias for stimulating and pleasant experiences.

The bias for happiness can be assimilated to approach tendencies according to the two basic systems of approach/withdrawal proposed by Bradley, Codispoti, Cuthbert, and Lang (2001) and Lang, Bradley, and Cuthbert (1999). These authors developed an appetitive/defensive motivational model that describes the structure of judgements for a set of affective pictures dedicated to emotion research. In this model, pictures judgements were projected in a valence/arousal space and organised along two distinct hypothetical appetitive or defensive motivational arrows that formed a boomerang shape. The two arrows represented stimuli that elicit appetitive and defensive reactions respectively. The most pleasant and arousing stimuli are grouped at one extreme of the appetitive arrow, whereas the most unpleasant and arousing ones are located at the extreme of the defensive arrow.

The structure of the emotional judgements obtained here with music and multidimensional scaling analysis was interpreted in terms of energetic and tension dimensions, but the solution is equally consistent with a model in terms of approach/withdrawal tendencies. The energetic dimension that contrasts sad and happy music may correspond to the appetitive arrow. Conversely, the tension dimension along which excerpts vary from peacefulness to threat may be assimilated to a defensive system. This parallel is in line with the biological perspective on musical emotions that points to their potential adaptive significance (Peretz, 2001).

More interestingly, the emotional structure proposed here in terms of energetic and tension dimension and obtained with auditory stimuli is fairly similar to the results obtained with human gestures communicating happy, sad, afraid and relax movements (Pollick, Paterson, Bruderlin, & Sanford, 2001). In the latter study, the visual perception of affect from point-light displays of arm movements was examined in a matching task in which participants were asked to associate affect labels to arms movements. A multidimensional scaling procedure revealed a two-dimensional solution in which dimension 1 opposed sad to happy arms movements, and dimension 2 contrasted relaxed from afraid movements. Dimension 1 was correlated with kinematics markers such as magnitude of velocity and acceleration of the movement. This kinematics dimension is similar to the energetic axis identified here. The second dimension did not correlate with the movement kinetics and was interpreted as a valence dimension. Thus, the emotional structure obtained from gestures is remarkably similar to the structure observed here with music. This cross-domain resemblance may promote integration of perception and action in musical settings. Body movement, musical gestures and emotion communication are interrelated in music performance, hence congruency across perception and action may explain this remarkable parallel.

In conclusion, the present set of musical stimuli appears suitable for research on emotion. For example, this set of stimuli allowed us to show that the amygdala is involved in the recognition of danger from auditory events, not just faces (Gosselin et al., 2005). The present set of validated stimuli can also be easily manipulated. Some structural characteristics (e.g., tempo) can be digitally modified with great ease so that the same music could communicate emotions in a gradual manner. This is why we present the full set of stimuli in musical notation, with the mean percentage of best label, the number of musical events required for correct recognition and the valence/arousal ratings in Appendix 2. We hope that the present material will be widely used as a tool for testing the perception of musical emotions in many research domains like, for instance, psychopathology. We also hope that it will contribute to the understanding of emotions across domains and modalities as well as in a cross-cultural perspective.

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APPENDIX 1

Ratings of overall dissonance (1 = not dissonant at all, 5 = very dissonant), of unexpected events (1 = expected, 5 = very unexpected), and of rhythmic regularity (1 = fairly regular, 5 = irregular) for the scary stimuli. The number of notes comprised in the stimuli and the frequencies of correct and confident recognition are also presented.

	Scary excerpts													
	P01	*P02*	*P03*	*P04*	*P05*	*P06*	*P07*	*P08*	*P09*	*P10*	*P11*	*P12*	*P13*	*P14*
Number of notes	28	23	27	7	18	45	8	38	6	12	12	11	20	28
Dissonance	3	1	1	2	3	2	2	3	1	2	4	1	3	2
Unexpected events	4	2	2	2	2	4	3	4	1	3	5	4	5	2
Regularity of rhythm	5	2	2	3	3	3	4	4	1	4	4	4	1	5
Freq. of correct rec.	0.7	0.1	0.9	0.8	0.8	1	0.2	0.7	1	0.9	0.7	0.5	1	0.7
Freq. of confident rec.	0.7	0.1	0.8	0.8	0.6	0.9	0.2	0.4	1	0.4	0.6	0.5	1	0.6

APPENDIX 2

The 40 stimuli used in Experiment 3 are presented in musical notation and organised by emotion category (''A'' for peacefulness; ''G'' for happiness; ''P'' for scary; and ''T'' for sadness). The shaded part corresponds to the portion of the stimulus that was presented in Experiment 1 but not in Experiment 3. The mean percentage of the best label derivation, the mean valence and arousal rating, and the number of events required for correct recognition are provided for each stimulus.

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
A01 	77	6.6	1.9	4.4
A02 	77	7.1	2.0	4.1
A03 	67	6.3	3.0	4.2
A04 	62	6.8	2.7	4.0

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
A05 	64	6.9	1.6	3.4
A07 	67	6.9	2.0	2.9
A10 	69	6.7	3.1	3.7
A11 	64	6.9	2.8	3.6
A12 	64	7.2	2.0	3.8

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
A13 	67	6.5	2.7	2.5
G01 	97	7.1	8.3	3.3
G02 	100	6.4	7.6	2.4
G03 	97	6.7	7.7	2.4

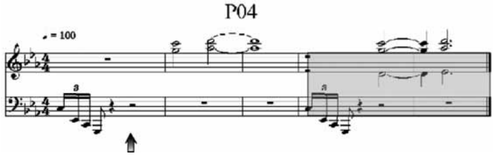
APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
G04 	100	7.1	8.6	2.0
G05 	100	6.6	8.4	2.1
G10 	97	6.1	8.1	2.1
G11 	100	7.0	7.6	2.5

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
G12 	95	6.6	8.1	2.8
G13 	97	7.1	8.4	3.3
G14 	100	6.5	6.7	2.0

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
P02 	95	4.4	8.5	4.4
P03 	95	5.2	8.5	4.6
P04 	90	3.5	7.0	4.4
P05 	82	4.3	7.5	4.8

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
P07 	77	3.4	7.4	4.7
P09 	82	2.0	6.6	2.0
P10 	82	2.9	6.6	5.4
P11 	69	2.6	6.1	2.5
P12 	74	3.0	7.4	2.4

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
P14 	67	4.0	8.1	4.1
T01 	100	4.6	2.6	2.7
T03 	95	6.0	1.8	3.3
T05 	79	5.2	2.8	3.1
T06 	79	6.0	2.0	2.1
T08 	77	5.3	2.0	3.4

APPENDIX 2 (*Continued*)

Musical notation and tempo	*Best label (%)*	*Valence (max. 9)*	*Arousal (max. 9)*	*Nb. of events*
T09 	90	5.7	2.9	2.5
T11 	82	4.7	2.9	2.8
T12 	79	5.5	1.9	2.9
T13 	79	5.0	3.4	2.7
T14 	69	5.7	2.0	2.9