Using music to induce emotions: Influences of musical preference and absorption

Gunter Kreutz, Ulrich Ott, Daniel Teichmann, Patrick Osawa and Dieter Vaitl

Psychology of Music 2008; 36; 101 originally published online Nov 12, 2007;
DOI: 10.1177/0305735607082623

Using music to induce emotions: Influences of musical preference and absorption

Psychology of Music
Psychology of Music

vol 36(1): 101–126 [0305-7356 (200801) 36:1; 101–126]
10.1177/0305735607082623
http://pom.sagepub.com

GUNTER KREUTZ
ROYAL NORTHERN COLLEGE OF MUSIC, UK
ULRICH OTT, DANIEL TEICHMANN, PATRICK OSAWA AND DIETER VAITL
UNIVERSITY OF GIESSEN, GERMANY

ABSTRACT The present research addresses the induction of emotion during music listening in adults using categorical and dimensional theories of emotion as background. It further explores the influences of musical preference and absorption trait on induced emotion. Twenty-five excerpts of classical music representing 'happiness', 'sadness', 'fear', 'anger' and 'peace' were presented individually to 99 adult participants. Participants rated the intensity of felt emotions as well as the pleasantness and arousal induced by each excerpt. Mean intensity ratings of target emotions were highest for 20 out of 25 excerpts. Pleasantness and arousal ratings led to three main clusters within the two-dimensional circumplex space. Preference for classical music significantly influenced specificity and intensity ratings across categories. Absorption trait significantly correlated with arousal ratings only. In sum, instrumental music appears effective for the induction of basic emotions in adult listeners. However, careful screening of participants in terms of their musical preferences should be mandatory.

KEYWORDS: *basic emotions, circumplex model, music listening*

Introduction

Psychological approaches to music listening, in general, and the induction of emotion, in particular, have been the subject of a wide range of research in recent years (e.g. Sloboda and Juslin, 2001). The present research addressed the induction of emotion while listening to instrumental classical music. Its goals were two-fold. First, by using categorical and dimensional models, the specificity and intensity of subjectively felt emotion were addressed. A second objective was to determine the influence of long-term individual differences, namely participants' musical background and preference as well as absorption trait. Stimulus materials were pre-selected instrumental music excerpts from the western classical repertoire representing 'happiness', 'sadness', 'fear', 'anger' and 'peace' (Kreutz et al., 2006).

The precise origins of emotional responses to music listening are unknown at present (Juslin and Sloboda, 2001). There is general consensus that both properties of stimulus materials and individual differences contribute significantly to the induction of musical emotion. It appears that variables on the sides of stimuli and recipients are to some degree inter-related. For example, Balkwill and Thompson (1999) point out that even when the music materials alone are considered, psychophysical and cultural cues need to be distinguished. The implication is that beyond the physical characteristics of music stimuli, emotional responses to music listening are significantly influenced by variables indicating cultural learning. Such learning processes are reflected in musical preference and experience. Moreover, individual differences and personality traits have also been observed as influencing emotional responses to music listening (McNamara and Ballard, 1999; Nater et al., 2005).

In the remainder of this introduction, we will review some of the empirical research on emotional responses to music listening. Specifically, we will address issues of modelling emotional responses, stimulus construction and individual differences.

Emotional responses to music listening are evidenced in everyday life (Sloboda et al., 2001), e.g. commercial environments (Alpert and Alpert, 1989) and film drama (Smith, 1999). Both philosophical accounts (e.g. Kivy, 1990) and empirical observations (e.g. Campbell, 1942; Clynes, 1977; Juslin et al., 2001–02) suggest that emotions expressible in music may be categorized in terms of a small number of basic emotions (Sloboda and Juslin, 2001: 76), which might have evolved from vocal communication (Jürgens, 2002; Juslin and Laukka, 2003). It appears that the expression of 'happiness' and 'sadness' is more often attributed to music than any other emotion, even in the absence of musical sound (Kreutz, 2002; Lindström et al., 2002). Reviews of the empirical literature confirm that aspects of composition (Gabrielsson and Lindström, 2001) and performance (Juslin, 2001; Sloboda and Lehmann, 2001) are important to the expression and communication of these as well as a small number of other so-called basic emotions (Ortony and Turner, 1990). For example, 'happiness', 'sadness', 'tenderness', 'fear' and 'anger' are often communicated by specific patterns of acoustic cues (Juslin et al., 2001–02: 72). Some of these cues, e.g. tempo and loudness, are not specific to music, whereas structural features such as scales and tonality are specific to a musical culture (Balkwill and Thompson, 1999).

Complementary to the basic emotion hypothesis, the so-called circumplex model has been proposed for the study of emotion. In most versions of this model, two orthogonal psychological dimensions are distinguished: valence (negative to positive) and arousal (low to high). It has been shown that these dimensions are sufficient to explain high percentages of variance for basic emotions (Russell, 1980), while much of the evidence is based on responses to stimuli other than music. Recently, however, Bigand et al. (2005) used a multidimensional scaling approach to investigate emotional responses to listening to music. The authors found that dimensions of arousal and emotional valence provided the best fit to similarity ratings of pairs of excerpts. They also observed that the results were not significantly influenced either by listeners' expertise or the duration of excerpts, which was reduced to one second (Bigand et al., 2005). An important aspect of the present study is the combination of categorical and dimensional approaches to emotion in the context of music listening, which requires a detailed analysis of relationships between the respective ratings representing each approach.

Subjective experience of emotion during music listening is perhaps the most important component of responses to music in adult listeners, whether it is understood in categorical or dimensional terms (e.g. Panksepp, 1995; Sloboda, 1991). To address emotion induction by music at this level, Gabrielsson distinguishes *perceived* emotion from *felt* emotion (Gabrielsson, 2001–02). Perceived emotion refers to intellectual processing, i.e. the perception of an intended or expressed emotional character (Kreutz et al., 2003), whereas felt emotions reflect the introspective perception of psychophysiological changes, which are often associated with emotional self-regulation (Khalfa et al., 2002; Thayer and Faith, 2001). For example, if listeners perceive a piece of music as 'happy', they may or may not be affected by a feeling of 'happiness' or 'elation' during listening (Robazza et al., 1994). Gabrielsson points out a number of theoretical relationships between emotion perceived and felt, namely positive, negative, not systematic or no relationship at all (Gabrielsson, 2001–02: 131).

Studies of musically induced emotions in laboratory settings by means of behavioural (Bigand et al., 2005; Carlton and MacDonald, 2003; Ritossa and Rikkard, 2004), peripheral physiological (Gupta and Gupta, 2005; Kreutz et al., 2002; Krumhansl, 1997; Nyklicek et al., 1997) or brain imaging methods (e.g. Brown et al., 2004) suggest that listeners tend to respond to specific emotional tones as conveyed in music excerpts. For example, Nyklicek et al. (1997) observed in their psychophysiological study that a breathing component was significantly related to subjective arousal, while other cardiovascular measures (inter-beat-interval and left ventricular ejection time) decreased for all emotions except for happiness. Similarly, Kreutz et al. (2002) showed that the perceived 'happy' or 'sad' tone of music excerpts was differentiated by a vagotone influence on the haemodynamic response. In general, these studies suggest that western classical music excerpts can effectively communicate at least a small number of emotions between composer, performer and listener. However, it is less clear whether music induces those basic emotions that can be located in four quadrants of the psychological space defined by the circumplex model (Russell, 1980). Theoretically, it is possible to validate emotion categories by their individual levels of valence and arousal within the circumplex model.

Emotional responses to music have also been studied in the context of the so-called Musical Mood Induction Procedure (MMIP; Västfjäll, 2001–02). Usually, research on MMIP addresses effects of music listening (often in comparison with other treatments) on subjective, behavioural, and/or physiological measures. In brief, music is used in mood induction research as a means to influence subsequent behaviour. By contrast, studies of the induction of emotions (instead of mood changes) can be placed in a more confined stimulus-response framework. However, MMIP research is relevant to the present endeavour for two reasons. First, the experimental literature suggests that MMIP is effective in inducing positive, negative and neutral moods in listeners. Second, most MMIP studies use self-referent mood adjectives. We use a similar procedure in the present study, where we address the awareness of particular emotional changes during and after listening to short excerpts of music.

STIMULUS SELECTION

Experimental research on emotion induction by music in the laboratory has relied on different strategies for stimulus selection and construction. These strategies include, for example, pre-selection of music by experts/experimenters versus self-selection by participants (Thaut and Davis, 1993). Obviously, pre-selection is necessary to construct generalized and reliable stimulus materials. However, while musical biographies and experiences differ widely across listeners (Gabrielsson, 1993), ecological validity and emotional responses are presumably greater if self-selected instead of pre-selected stimuli are used (Blood and Zatorre, 2001). Therefore, it is important to address variables such as familiarity, liking and pleasantness in studies using pre-selected stimuli (Ritossa and Rickard, 2004).

In order to study the emotional effects of listening to music, researchers have often used commercially available recordings of music from various genres (e.g. De Vries, 1991; Gregory and Varney, 1996; Kreutz et al., 2002, 2003; Robazza et al., 1994) as well as pieces of music that were specifically performed (Nair et al., 2002; Sloboda and Lehmann, 2001) or composed for experimental purposes (Dalla Bella et al., 2001; Hevner, 1935; Peretz et al., 1998; Scherer and Oshinsky, 1977; Webster and Weir, 2005). While a few studies include genres such as jazz (e.g. Wallach and Greenberg, 1960), pop (North and Hargreaves, 1997), or Indian ragas (Balkwill and Thompson, 1999; Gregory and Varney, 1996; Gupta and Gupta, 2005), the majority used commercial recordings of western instrumental classical music. In fact, it can be assumed that many of the compositions in western music between 1600 and 1900 were designed to communicate and induce emotions in ordinary listeners. Therefore, it is not surprising that according to Västfjäll's (2001–02) survey of MMIP cited above, this research is dominated by the use of western classical music (Västfjäll, 2001–02: 176). Analyses of the structural features of particular compositions seem to support their suitability to communicate emotions (Gabrielsson and Lindström, 2001). Moreover, the analysis of variations of timing and intensity changes in the acoustic signal reveals that at this level, information representing specific emotions is communicated to the listener (Juslin, 2001). Profiles of performance measures related to the same set of emotions in speech and music were found to be highly similar (Juslin and Laukka, 2003).

INDIVIDUAL DIFFERENCES: ABSORPTION, MUSICAL BACKGROUND AND PREFERENCE

In this study, the trait of absorption (Tellegen and Atkinson, 1974) was chosen to reflect emotional responsiveness for several reasons. First, music listening is often associated with kinds of altered states of consciousness, for example, in the context of meditation, trance and religious experiences (Hills and Argyle, 1998; Miller and Strongman, 2002). The Tellegen Absorption Scale (TAS) measures the openness to enter altered states such as these. Second, the intense emotional response to aesthetic stimuli (beauty of nature, poetry, music) is well represented by the absorption trait as measured by the TAS. The scale includes items such as: 'When I listen to music I can get so caught up in it that I don't notice anything else', and: 'When listening to organ music or other powerful music I sometimes feel as if I am being lifted into the air'. Responsiveness to musical stimuli, as addressed by these items, varies considerably between individuals. However, to date, the relationships between absorption and emotional responses during music listening have rarely been investigated systematically. In one of these studies, Snodgrass and Lynn (1989) found different response patterns to music listening in participants characterized as highly hypnotizable as compared to those who were labelled as low hypnotizable. However, participants who were hypnotizable to an intermediate degree were indistinguishable from the extreme groups. Further evidence for the influence of absorption was provided by the study of Wild et al. (1995). They found that TAS scores correlated significantly with the ability of music 'to influence participants' feelings' ($N = 68$, $r = .50$, $p < .001$), which they rated on a seven-point scale. It seems plausible to expect a similar influence of the absorption trait on the intensity of evoked emotions in an experimental setting.

A key feature of the absorption trait is the ability to focus attention on one particular object, while other stimuli are completely ignored. Participants scoring high on absorption should be less disturbed by a laboratory setting during emotion induction because of their ability to 'forget' their surroundings. Objects of absorbed attention can be internal events such as a daydream or a memory as well as external stimuli such as a beautiful sunset, a fascinating story or a piece of moving music (see items above). According to Tellegen and Atkinson (1974), absorption is manifested in states of 'total attention', where all mental resources are engaged, and they stress the importance of empathic identification for this mobilization of resources. Many items of the TAS indicate a strong emotional involvement, e.g. 'I can be deeply moved by a sunset'. In the case of music listening, such identification with the feelings expressed through the music is essential for emotion induction. The trait of absorption includes the openness to being deeply affected by stimuli such as music and was expected to explain part of the inter-individual variability in emotional responses to musical stimuli.

Individual differences in musical behaviour have been studied in the past with respect to the performer (e.g. Kemp, 1997) as well as to the listener (Kreutz et al., 2002; Robazza et al., 1994). Relationships between personality traits, intensity of listening, and sensitivity to music have been documented (Lewis and Schmidt, 1991). However, there is a paucity of research that addresses personality traits and emotional responses to music (cf. Abeles and Chung, 1996).

It is not surprising that musical training has been considered to be one of the most important facets that might influence emotional and affective responses to music. In many studies, musical training or expertise is defined on the basis of ad hoc questionnaires, which are administered to different groups of participants. Therefore, in considering empirical studies, listeners are classified as musically trained on the basis of widely differing criteria, which may render comparisons across studies problematic (see Abeles and Chung, 1996, for a review).

Formal training on musical instruments is often initiated in early childhood and may persist through adolescence (Davidson et al., 1997). Musical training can lead to enhanced cognitive processing, e.g. of subtle changes within musical pitch patterns (Koelsch et al., 1999), as well as to significantly stronger mood/emotional responses while listening to classical as compared to popular music (Sopchack, 1955), or to stronger responses across different styles (Brennis, 1970). Other researchers have highlighted similarities across groups of differentially trained listeners in psychological and physiological responses to musical tension in isolated chords and tonal chord progressions (Koelsch et al., 2000; Winold, 1963). Whether these divergent findings are the result of varying classification criteria or other task- or stimulus-related factors is not clear, which in turn necessitates clear definitions of both levels of training and music stimuli (Abeles and Chung, 1996: 301).

HYPOTHESES

It was expected that musically induced emotions would lead to significantly higher ratings of the intended emotion category as compared to the other categories for all 25 stimuli chosen for this study. Moreover, it was hypothesized that valence and arousal ratings would mirror emotion categories in accordance with the circumplex model (Russell, 1980).

The second set of hypotheses addressed relationships between some of the participants' long-term characteristics on the one hand, and their short-term responses to music listening on the other. It was expected that positive correlations would exist between the absorption trait and the intensity of induced emotions. It was also expected that musical training and preference would significantly influence both specificity and intensity of emotional responses.

As the main focus of the study addresses trait variables, it appears important to rule out the influence of confounds associated with participants' situational moods. To control for momentary emotional states, participants provided mood ratings before and after the experiment. Finally, only minor influences of familiarity with the musical materials were assumed, as previous studies (e.g. Ritossa and Rickard, 2004) suggest no systematic influences of this variable on subjective valence and arousal.

Method

PARTICIPANTS

Participants ($N = 99$; 80 female) were recruited through postings on the bulletin board of the Psychology Department at the University of Giessen, Germany. Their ages ranged from 17 to 43 years ($M = 24.8$, SD = 5.5 years). All participants, predominantly undergraduate psychology students, received certification of their participation, which is required for their first diploma.

MATERIALS

Stimuli

Twenty-five musical stimuli were selected from the classical instrumental music repertoire (titles and composers are listed in Appendix 1), five excerpts representing one of five emotion categories: 'happiness', 'sadness', 'fear', 'anger' and 'peace'. 'Happy' and 'sad' stimuli were administered from a previous study (Kreutz et al., 2003). The authors selected excerpts representing the remaining emotion categories after a screening process, which included a large sample of classical music. Only pieces that achieved unanimous judgments by three of the authors (GK, UO, DT) regarding their suitability to represent one specific emotion within the five categories were chosen for the study.

The pieces containing the excerpts were copied to a personal computer. Digital sound processing software (CoolEdit 2000® from Syntrillium) was used to edit the experimental excerpts and to normalize their loudness levels after editing. To minimize any sound distortions induced through the editing process, samples were faded in and out using one-second rise and decay times. Finally, the 25 excerpts were copied as separate tracks on an audio CD in pseudo-randomized order. It was ensured manually that pairs of successive excerpts did not represent the same intended emotion. The experimental CD also contained an extra track at the beginning to be used for loudness adjustments. To control for order effects, a second CD was created containing the stimuli in reverse order.

Questionnaires

Participants provided basic demographic data and information about individual musical backgrounds on the front page of the music listening questionnaire. This page also included instructions and response items for the practice trial. Several items addressed the amount of musical training (playing instruments and singing), music preferences, and music consumption per day. Participants could choose from the following list of expertise levels: 'non-musician', 'occasional playing musical instruments (only for fun)', 'amateur (serious interest in playing, but non-professional)', 'semi-professional (earning up to half of monthly personal income by playing music)' and 'professional (playing music or singing as main profession)'. Participants were further requested to rate the importance of music-making to them (if musicians), listening to music, emotional empathy during music listening, altered state of consciousness during music listening, and liking for and frequency of classical music listening, on seven-point Likert-type scales. To measure the absorption trait, the German version of the TAS (Ritz and Dahme, 1995) was administered.

The response sheet for the listening and experiment consisted of a further 25 pages, each containing rating scales for felt emotions, valence, arousal and familiarity, with one page for each musical excerpt. The intensity of each of the five emotions ('happy', 'sad', 'anger', 'fear', 'peace') felt during listening was rated separately on seven-point scales ranging from 'not at all' (coded as '0') to 'very strongly' (coded as '6'). Similarly, listeners rated valence (ranging from 'unpleasant' to 'pleasant') and arousal (ranging from 'not activating' to 'activating') while the music was played. The last item required participants to tick a box in order to specify if they knew the piece or not. On the last page, they were asked to rate their overall liking of the musical excerpts and the frequency of exposure to this kind of music in their everyday lives. Finally, participants were asked to rate their momentary mood on several scales, which included 'tired', 'tense', 'fearful', 'angry', 'joyful' and 'peaceful'.

PROCEDURE

Participants were tested individually and the procedure was identical for all of them. They first completed the demographic, musical background and absorption trait questionnaires, while being seated comfortably on a reclining chair. They were then instructed how to operate the CD Player (Technics SL-PG 420A) using the remote control and how to adjust loudness levels on their head phones to a comfortable level (Sennheiser HD 495). Participants were requested to fill in the mood questionnaire first and then rate each excerpt immediately after listening. The light was dimmed and the participants were left alone during the experiment in order to create a private atmosphere. The session finished after participants signalled completion of the listening experiment and of the post-experiment mood questionnaire to the experimenter.

DATA PROCESSING AND STATISTICAL METHODS

Mean ratings were calculated for each of the 25 pieces. The specificity of each piece to represent its intended emotion category was tested by students' *t*-tests. The mean rating of the intended emotion was compared to the four other categories. Since significant differences between target and alternative emotions were postulated, the *p*-values of the four single *t*-tests were used to calculate a cumulative *p*-value denoting the probability that the rating of the target emotion (E_T) was higher than each of the four other emotions (E_N):

$$H_1: E_T > E_1 \wedge E_T > E_2 \vee E_T > E_3 \vee E_T > E_4.$$

The corresponding null hypothesis reads:

$$H_0: E_T = E_1 \wedge E_T = E_2 \vee E_T = E_3 \vee E_T = E_4.$$

The *p*-value for specificity is calculated as the family-wise probability of the four single hypotheses (p_N) of H_0, determined by one-tailed pair-wise *t*-tests:

$$p = 1 - [(1 - p_1) * (1 - p_2) * (1 - p_3) * (1 - p_4)].$$

In those cases where no significant difference at the group level was obtained, a second analysis was performed that addressed the specificity of emotional responses at the individual level. In this analysis, instead of the intended emotional category ratings, the highest ratings from each individual, aggregated across the entire sample, were compared to the remaining categories using the same formula described above.

Valence and arousal ratings were submitted to a confirmatory centroid cluster analysis (Everitt et al., 2001) in which five clusters – one for each emotion category – were entered.

The *intensity* of emotional responses (I_{emot}) was calculated for each subject by averaging the ratings of the target emotions across the five pieces in each category. In order to obtain an individual measure for the global intensity of experienced emotions (I_{glob}), the highest emotion ratings for each of the 25 pieces were averaged irrespective of target emotions. Hence, the *specificity* of emotional responses (S_{emot}) was calculated by subtracting the average ratings of the non-target emotions from I_{emot}.

The absorption trait was assessed for each individual by calculating a sum score as described by Ritz and Dahme (1995). The score was entered as an independent variable into several regression analyses, in which emotion induction ratings served as dependent variables.

Participants were differentiated in terms of their musical expertise on the basis of their responses to six music items in the questionnaire, all of which were related to formal musical training and singing. Number of years of formal musical training and self-rated level of expertise were used as the primary criteria to determine musicianship. To accommodate the expected low levels of training among the psychology students used in this study, additional items from the questionnaire relating to active singing in choirs were included in the criteria. Two extreme groups of musical expertise were constructed. Participants were assigned to the 'high expertise' group if they rated themselves as 'amateur', 'semi-professional', or 'professional'. A second criterion was a minimum of three years of formal musical training. Participants were assigned to the 'low expertise' group if they rated themselves as 'non-musicians'. Further inclusion criteria for this group were no formal musical training and no choir singing at present or in the past.

The level of statistical significance was set to alpha = .05 in all analyses.

Results

Prior to addressing the research hypotheses, absorption, musical background and any relationships between these long-term characteristics and the general liking of the experimental stimuli were examined. Moreover, mood changes during the experiment were assessed.

ABSORPTION TRAIT

The mean and standard deviation of the sample ($M = 65.38$; SD = 18.75) approximate the normative data reported by Ritz and Dahme (1995): $M = 60.05$; SD = 19.98. The slightly elevated mean score of the present sample is due to the high percentage of female participants who score higher in comparison with males (Ritz and Dahme, 1995).

MUSICAL BACKGROUND AND PREFERENCE

The majority of participants rated themselves as either 'non-musician' (45%) or 'occasional player' (41%). The remaining participants classified themselves as 'amateur' (10%), 'semi-professional' (2%) or 'professional' (1%). Thirteen participants in the latter three groups had a minimum of at least three years of musical training. They were collapsed into a 'high expertise' group for subsequent analyses. By contrast, participants in the 'low expertise' group were all 'non-musicians' with no formal musical training at all.

In addition to musical performance level, several other aspects of musical experience and preferences were assessed. Preference for classical music in general was assessed as well as liking of the stimuli presented to the participants.

MOOD BEFORE AND AFTER THE EXPERIMENT

Affective state was assessed to control for situational influences on emotion ratings. In general, the participants reported to be in a 'peaceful' and 'relaxed' mood. Lowest levels of affect were found for 'anger' and 'fear' scales. The rare occurrence of intensive negative emotions precluded an analysis of systematic influence of affective states. With respect to affective state changes, significant reductions of tiredness ($t = 2.56$, $p = .012$) and tension ($t = 2.24$, $p = .028$) were noted, while sadness was the only emotion that showed a significant increase ($t = -2.02$, $p = .046$).

INDUCED EMOTIONS AND INDIVIDUAL DIFFERENCES

The analyses of individual differences of induced emotions were based on intensity scores for each emotional category (I_{emot}) and on a global measure for intensity (I_{glob}) derived from the highest emotion ratings (see 'Methods' earlier). The mean activation ratings of the participants were also included because arousal of autonomic and motor systems was considered an important aspect of emotional responsiveness.

Induced emotions

Table 1 shows comparisons of mean ratings of felt emotions for each piece of music as grouped by their intended category. In 20 out of 25 cases, participants gave significantly higher ratings for the intended emotion than for any other category. The five exceptions to this pattern will be dealt with later.

TABLE 1 *Means (and standard deviations) of induced emotions for each musical excerpt*

Category (a priori)	Excerpt	Mean ratings of induced emotions					Specificity (p-value)
		Happiness	Sadness	Anger	Fear	Peace	
Happiness	1	**4.4 (1.7)**	0.2 (0.7)	0.2 (0.9)	0.0 (0.2)	**2.2 (2.0)**	.001
	2	**4.5 (1.6)**	0.2 (0.7)	0.2 (0.7)	0.1 (0.2)	**2.2 (2.2)**	.001
	3	**4.6 (1.6)**	0.2 (0.6)	0.2 (0.8)	0.1 (0.5)	**2.4 (2.1)**	.001
	4	**4.4 (1.3)**	0.2 (0.5)	0.2 (0.6)	0.1 (0.3)	**2.3 (1.9)**	.001
	5	**4.2 (1.5)**	0.3 (0.8)	0.1 (0.5)	0.1 (0.6)	**2.9 (1.9)**	.001
Sadness	1	0.6 (1.2)	**4.2 (1.8)**	0.3 (0.8)	0.8 (1.3)	**3.2 (2.0)**	.001
	2	1.1 (1.5)	**3.4 (1.9)**	0.3 (0.8)	0.6 (1.3)	**3.6 (2.2)**	.213
	3	0.6 (1.1)	**4.3 (1.8)**	0.3 (0.9)	0.7 (1.3)	**2.9 (2.2)**	.001
	4	1.5 (1.6)	**2.8 (2.1)**	0.1 (0.4)	0.4 (1.0)	**4.6 (1.7)**	n.s.*
	5	0.6 (1.0)	**4.1 (1.7)**	0.3 (0.7)	0.7 (1.2)	**3.3 (2.1)**	.002
Anger	1	0.9 (1.5)	0.7 (1.2)	**2.7 (2.0)**	**1.8 (1.9)**	0.5 (1.1)	.001
	2	0.4 (0.9)	0.6 (1.2)	**2.5 (2.1)**	**3.2 (2.2)**	0.3 (0.9)	n.s.*
	3	1.3 (1.6)	0.4 (0.8)	**2.2 (1.8)**	**1.7 (1.9)**	0.6 (1.3)	.010
	4	**1.6 (1.7)**	0.4 (0.9)	**2.0 (1.9)**	1.2 (1.6)	0.5 (1.1)	.060
	5	1.1 (1.4)	0.5 (1.0)	**2.0 (1.8)**	**1.3 (1.6)**	0.6 (1.2)	.001
Fear	1	0.5 (1.2)	0.5 (1.1)	**2.1 (1.9)**	**2.8 (2.2)**	0.5 (1.1)	.006
	2	0.2 (0.7)	0.6 (1.2)	**2.5 (2.4)**	**3.4 (2.4)**	0.3 (1.1)	.002
	3	1.0 (1.5)	0.4 (0.9)	**1.5 (1.8)**	**2.2 (2.2)**	0.6 (1.3)	.004
	4	0.5 (1.0)	0.5 (1.1)	**2.5 (2.1)**	**2.8 (2.2)**	0.6 (1.3)	.112
	5	0.9 (1.3)	0.7 (1.2)	**1.7 (1.8)**	**2.4 (2.1)**	0.5 (1.1)	.003
Peace	1	**2.4 (1.9)**	1.5 (1.7)	0.1 (0.5)	0.2 (0.6)	**4.5 (1.4)**	.001
	2	1.6 (1.5)	**2.2 (1.9)**	0.1 (0.3)	0.2 (0.6)	**4.5 (1.6)**	.001
	3	1.5 (1.6)	**2.4 (2.1)**	0.1 (0.5)	0.4 (0.9)	**3.9 (1.7)**	.001
	4	**2.2 (1.9)**	1.7 (1.9)	0.2 (0.6)	0.2 (0.7)	**4.8 (1.4)**	.001
	5	2.1 (2.0)	**2.4 (2.1)**	0.1 (0.3)	0.3 (0.8)	**5.0 (1.5)**	.001

Note: p-values in the last column indicate specificity of the excerpts for the intended emotion (see 'Methods' section earlier). Highest and second highest ratings are bold. * Sadness no. 4 is specific for peace ($p = .001$); anger no. 2 is specific for fear ($p = .007$).

With respect to 'happiness' and 'peace', the induction of intended emotions was both uniform and strong across all 10 music excerpts. Within the three remaining categories, at least three pieces per category were found to induce the corresponding emotion. One piece among the 'sadness' pieces (no. 2) was ambiguous in that 'peace' and 'sadness' were rated at the same level. Moreover, the fourth excerpt in this category achieved the highest ratings in the 'peace' category. Felt emotions of pieces within the 'fear' and 'anger' categories were markedly weaker than for excerpts representing the three other emotions. Yet, the majority of excerpts did induce the intended emotion. The three excerpts, which did not follow this pattern, were either confused ('anger' no. 2) or ambiguous ('anger' no. 4 and 'fear' no. 4) between these categories. In sum, the overall pattern of ratings shows predominantly positive relationships between intended and felt emotions.

The three ambiguous pieces, which failed to show specificity on the group level were examined subsequently on the individual level. It was determined whether the pieces induced both emotions equally or rather single emotions alternating across participants.

To this end, the highest individual emotion ratings were tested across participants against the other four ratings sorted in descending order for each subject. Table 2 shows that the pieces specifically induced a single emotion in each subject.

The differences between highest and second highest ratings reached the same order of magnitude as those of the pieces, which were specific for only one emotion (see Table 1).

VALENCE AND AROUSAL

Figure 1 represents the 25 music excerpts projected into the two-dimensional circumplex diagram according to their respective mean valence and arousal ratings (Table 3). Moreover the diagram depicts the solution of a confirmatory centroid cluster analysis performed on these ratings with one exception. Because cluster analysis results might be severely affected by outliers (Everitt et al., 2001), the second excerpt in the 'fear' category (see Appendix), which was classified as an outlier, was eliminated from the analysis. Five centroids, one for each intended emotion category, were entered into the analysis. Valence and arousal ratings were greatest for excerpts in the 'happy' category. Excerpts inducing 'fear' and 'anger' were both characterized by negative valence and high arousal, while excerpts inducing 'peace' and 'sadness' were characterized by positive valence and low arousal. Thus, three main clusters emerge at first glance. However, a closer inspection reveals that, with one exception, the pieces of the 'anger' category obtained higher arousal and valence ratings than those of the 'fear' category. A similar differentiation exists between 'peace' and 'sadness' in so far as the peaceful excerpts were felt more positive and arousing (see Table 3). Contrary to the theoretical assumption of the circumplex model, pieces in the 'sadness' category received positive valence ratings, leaving the low arousal/low valence quadrant empty. Consequently, the centroids for the two pairs of categories just mentioned had the smallest distances (Table 4).

The question arises of whether the close proximity of the 'fear' and 'anger' as well as 'peace' and 'sadness' clusters is due to the ambiguity of some stimuli described above. In order to minimize this influence, a second analysis was performed that was based solely on the subjectively felt emotions. At first, only those cases were considered where a single emotion obtained a rating higher than three (midpoint of the scale), while all other emotions were rated lower than three and contributed thereby only

TABLE 2 *Means (and standard deviations) of induced emotions for the three 'ambiguous' music excerpts from Table 1*

Category (a priori)	Excerpt	Means of ratings sorted in ascending order: Lowest				Highest	Individual specificity (p-value)
Sadness	2	0,0 (0,2)	0,2 (0,7)	1,2 (1,3)	**2,7 (1,9)**	**4,7 (1,3)**	.001
Anger	4	0,1 (0,3)	0,2 (0,5)	0,6 (0,9)	**1,5 (1,4)**	**3,3 (1,7)**	.001
Fear	4	0,1 (0,3)	0,2 (0,5)	0,7 (1,1)	**1,9 (1,8)**	**4,0 (1,6)**	.001

Note: Ratings are sorted in ascending order for each subject before being submitted to the same statistical test for specificity. Thus, p-values indicate whether participants experienced one emotion per excerpt more intensely than any other emotion. Highest and second highest ratings are bold.

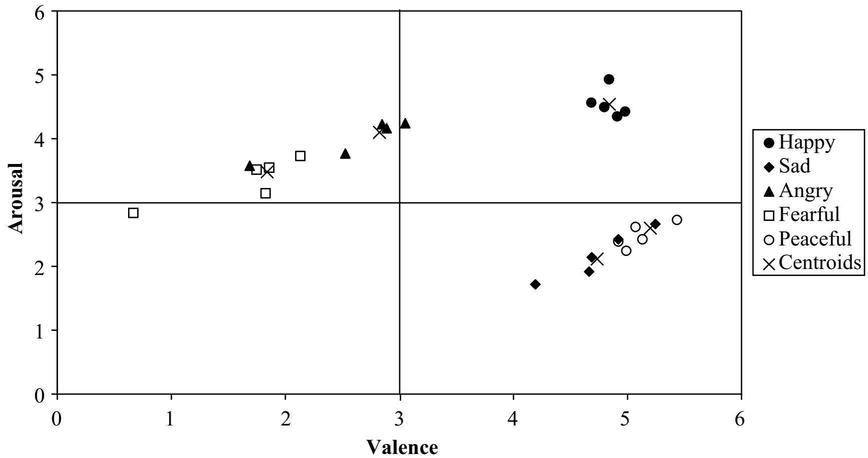

FIGURE 1 *Circumplex diagram representing mean valence and arousal ratings of the 25 music pieces (0 = low arousal; 6 = high arousal; 0 = negative valence; 6 = positive valence); the centroids of a cluster analysis are also shown (see text).*

TABLE 3 *Means (standard deviations) of valence and activation for the stimuli of all emotion categories*

		Stimulus					
Category	Rating	1	2	3	4	5	Mean
Happiness	Valence	4.7 (1.5)	4.8 (1.5)	4.8 (1.4)	5.0 (1.2)	4.9 (1.2)	4.8
	Arousal	4.6 (1.4)	4.9 (1.3)	4.5 (1.4)	4.4 (1.4)	4.3 (1.4)	4.6
Sadness	Valence	4.7 (1.4)	4.9 (1.4)	4.7 (1.4)	5.2 (1.1)	4.2 (1.6)	4.7
	Arousal	1.9 (1.7)	2.4 (1.8)	2.1 (1.8)	2.7 (1.8)	1.7 (1.6)	2.2
Anger	Valence	2.8 (1.7)	1.7 (1.6)	3.1 (1.7)	2.9 (1.6)	2.5 (1.6)	2.6
	Arousal	4.2 (1.7)	3.6 (2.0)	4.2 (1.6)	4.2 (1.8)	3.8 (1.7)	4.0
Fear	Valence	1.7 (1.5)	0.7 (1.4)	2.1 (1.7)	1.9 (1.7)	1.8 (1.5)	1.6
	Arousal	3.5 (2.0)	2.8 (2.3)	3.7 (1.7)	3.5 (1.9)	3.1 (1.8)	3.4
Peace	Valence	5.1 (1.2)	5.0 (1.2)	4.9 (1.2)	5.1 (1.2)	5.4 (1.0)	5.1
	Arousal	2.6 (1.6)	2.2 (1.6)	2.4 (1.6)	2.4 (1.6)	2.7 (1.8)	2.5

marginally to the felt arousal and valence. Table 5 presents the number of cases for each emotion and the ratings ranging from four to six. Second, the valence and arousal ratings were averaged across the selected cases and plotted into the circumplex space. Figure 2 shows the corresponding means as well as the mean of those pieces that obtained ratings lower than 3 for all emotions. The latter category thus represents emotionally weak or 'neutral' musical stimulation.

Figure 2 reveals that increasing intensity of the felt emotion influences valence and arousal differently. Increasing ‘happiness’, ‘anger’, and ‘fear’ ratings are associated with simultaneous increases in arousal and positive or negative valence. In all cases, a nearly

TABLE 4 *Cluster analysis: classification of stimuli, position of the five centroids and their distances*

Cluster	1	2	3	4	5
Label	Peace	Fear	Sadness	Happiness	Anger
Target pieces	1, 4, 5	1, 3, 4, 5 #	1, 2, 3, 5	1, 2, 3, 4, 5	1, 3, 4, 5
Other pieces	Sadness 4*	Anger 2*	Peace 2, 3	-	-
Valence	5.2	1.8	4.7	4.8	2.8
Arousal	2.6	3.5	2.1	4.5	4.1
Distances					
2	3.5				
3	0.7	3.2			
4	2.0	3.2	2.4		
5	2.8	1.2	2.8	2.1	

Note: * Piece has been found to be specific for this target category (see note to Table 1); # Fear no. 2 was not entered in the cluster analysis (see text).

TABLE 5 *Ratings with one dominating emotion, while all other emotions were rated below 3; number of cases, and means (standard deviations) for valence and arousal*

		Ratings		
Emotion		4	5	6
Happiness	N	82	62	61
	Valence	4.6 (1.0)	4.9 (1.0)	5.6 (0.6)
	Arousal	4.6 (0.9)	4.8 (1.0)	5.4 (1.0)
Sadness	N	36	41	19
	Valence	4.3 (1.4)	4.2 (1.8)	4.4 (1.4)
	Arousal	2.1 (1.5)	2.3 (1.7)	2.7 (2.0)
Anger	N	67	35	25
	Valence	2.2 (1.5)	1.6 (1.5)	0.6 (0.9)
	Arousal	3.6 (1.8)	3.8 (2.1)	4.3 (2.4)
Fear	N	52	47	38
	Valence	1.6 (1.2)	1.4 (1.4)	0.8 (1.4)
	Arousal	3.5 (1.9)	3.3 (2.1)*	3.9 (2.2)
Peace	N	61	83	53
	Valence	4.7 (1.1)	5.1 (1.2)	5.8 (0.6)
	Arousal	2.4 (1.5)	2.4 (1.5)	2.4 (1.8)
	(highest rating)	2	1	0
Neutral	N	162	83	69
	Valence	2.6 (1.6)	2.1 (1.4)	1.9 (1.8)
	Arousal	3.1 (1.9)	3.1 (1.7)	2.4 (1.9)

Note: * decrease because of one subject who rated four times Arousal = 0; without this subject: 3.6 (1.9).

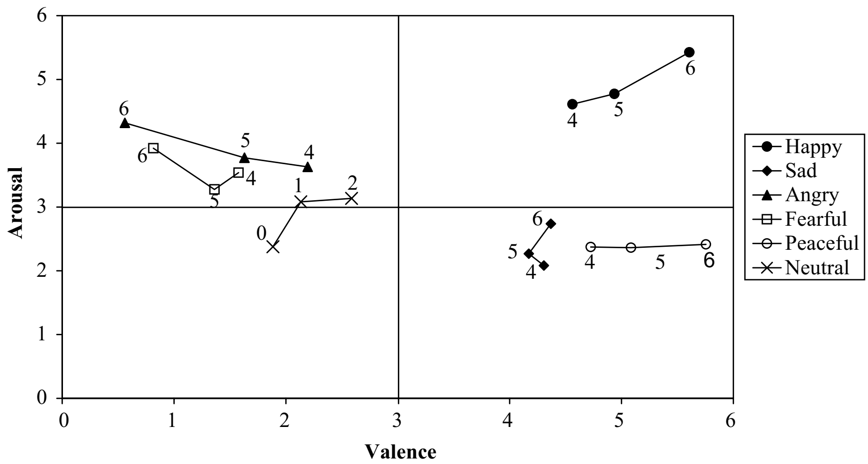

FIGURE 2 *Circumplex diagram based on ratings of unequivocal emotional responses and neutral ratings (all emotions < 2; 0 = low arousal; 6 = high arousal; 0 = negative valence; 6 = positive valence).*

TABLE 6 *Distribution of valence and arousal values irrespective of emotions*

		Valence			
	N	Low	Middle	High	
	High	342	421	833	1296
Arousal	Middle	280	432	654	1067
	Low	286	288	539	899
		713	814	1528	2475

Note: The ratings were assigned to three non-exclusive categories, which have been arranged in correspondence with the circumplex diagram: low = 0, 1, 2; middle = 2, 3, 4; high = 4, 5, 6.

linear tendency is found. Within this tendency, the step from 4 to 5 is consistently smaller than the step from 5 to 6. It seems likely that this observation is due to a rating bias toward the extreme ends of the scale. Increases in subjective 'sadness' and 'peace' are associated with one dimension only: 'peace' is associated with positive feelings without changes of arousal level, whereas 'sadness' is associated with changes of arousal only.

For experimental studies intending to investigate effects of valence and arousal on physiological parameters, distributions of valence and arousal values across all four quadrants are desirable. In Figures 1 and 2, some areas, particularly in the lower left quadrant, seem to be almost empty. However, this effect is due to the selection of values based on musical pieces and emotional ratings. Table 6 shows that in fact all combinations of low, middle and high valence and arousal values occurred. While distributions of valence and arousal ratings are skewed towards the positive ends of each scale, a substantial number of ratings are nevertheless located in the lower left quadrant of the circumplex model (low valence and low arousal). On average, approximately three low valence/low arousal ratings from a total of 25 combinations were observed, i.e. 12 percent (286 ratings/99 participants = 2.9).

TABLE 7 *Correlation coefficients of absorption scores and intensity of induced emotions; one-tailed* p-*values in parentheses*

	Absorption score	(1)	(2)
(1) Activation ratings	.245 (.007)	-	-
(2) Global intensity (I_{glob})	.249 (.006)	.298 (.001)	-
Emotion intensity (I_{emot})			
- happy	.151 (.067)	.323 (.001)	.690 (.001)
- sad	.187 (.032)	.251 (.006)	.669 (.001)
- angry	.067 (.255)	.202 (.023)	.667 (.001)
- fearful	.108 (.144)	.313 (.001)	.700 (.001)
- peaceful	.097 (.169)	.240 (.008)	.527 (.001)

TABLE 8 *Mean intensity (and standard deviations) of emotional responses in the extreme groups with different musical expertise; last column: one-tailed* p-*values of* U-*tests*

	Low expertise	High expertise	p-value
N	13	13	
Activation ratings	3.0 (0.5)	3.5 (0.8)	.024
Global intensity (I_{glob})	4.7 (0.9)	4.1 (0.9)	n. s. #
Emotion intensity (I_{emot})			
- happy	4.7 (1.4)	4.0 (1.4)	n. s.
- sad	4.1 (1.6)	3.3 (1.6)	n. s. #
- angry	2.7 (1.7)	1.9 (1.2)	n. s.
- fearful	3.4 (1.9)	2.2 (1.9)	n. s.
- peaceful	4.4 (1.4)	4.5 (1.1)	n. s.

Note: # a significant difference in the opposite direction was present.

ABSORPTION

The first hypothesis postulated a positive relationship between absorption trait and intensity of experienced emotions. Table 7 shows the result of a correlational analysis performed to test this hypothesis.

Participants scoring high on the absorption scale reported stronger emotions in general but not for any particular emotion, except that there was a significant correlation coefficient for ‘sadness’. Activation ratings were correlated with emotion ratings of all categories, including ‘peace’. The high correlations in the last column of Table 7 should be interpreted with caution because they might result from different response styles. The tendency of some listeners to either use the entire scale or to give only numerically low ratings could influence mean ratings as well as the global intensity measure.

MUSICAL EXPERTISE AND PREFERENCE FOR CLASSICAL MUSIC

Ratings of induced emotions from the two groups, which were identified with ‘high’ and ‘low’ musical proficiency, were compared by means of U-tests because of the small group sizes. Table 8 lists the means of the emotional responses in both groups and one-tailed *p*-values of the tests for differences because stronger responses had been postulated for the high expertise group.

The comparison revealed only one difference in the expected direction. Participants with high musical expertise gave higher activation ratings. All other measures showed no difference or even higher emotional responses in the low expertise group. A similar comparison of the specificity scores again revealed no significant differences between these groups of participants.

The preference for classical music was assessed with two questions concerning the liking of classical music and its selection for listening. Both items were highly correlated ($r = .634$, $p < .001$) and therefore they were combined into a single classical preference score by adding the numerical values of both answers. Table 9 shows the correlation coefficients of classical preference with intensity and specificity scores of induced emotions. Here, mean valence ratings were included because it was expected that a preference for classical music would result in more positive responses to the stimuli. The preference for classical music was indeed correlated with the global measures as well as the intensity and specificity scores of the happy and peaceful excerpts.

REGRESSION ANALYSES

Next, regression analyses were performed in order to determine the variance of the emotional responses explained by the different subject variables. Gender, preference for classical music and absorption score were used to predict valence, arousal, global intensity of induced emotions and the 10 emotion-specific intensity and specificity measures. Musical expertise was considered too complex and heterogeneous a variable to be represented by a single numerical value or three coarse categories of low, medium and high expertise with low predictive power.

The results of the 13 regression analyses are summarized in Table 10. First, gender and classical preference were entered in model 1, then absorption was included in model 2 in order to quantify the increase in explained variance obtained through the inclusion of this personality trait. Only variables producing significant coefficients in the multiple regression analysis were considered.

TABLE 9 *Correlation coefficients of preference for classical music with measures of the intensity and specificity of induced emotions; one-tailed p-values in parentheses*

Valence ratings	.463 (.001)	
Activation ratings	.371 (.001)	
Global intensity (I_{glob})	.230 (.011)	
Emotion category	Intensity (I_{emot})	Specificity (I_{spec})
- happy	.282 (.002)	.311 (.001)
- sad	.177 (.040)	.111 (.136)
- angry	.111 (.136)	.133 (.094)
- fearful	.040 (.348)	.045 (.328)
- peaceful	.266 (.004)	.200 (.024)

TABLE 10 *Condensed results of 13 regression analyses (method = enter)*

	Corrected R^2		Significance (p-value)					
	Model		Model		Gender		Preference	
Dependent variables	Mod. 1	Mod. 2	Mod. 1	Mod. 2	Mod. 1	Mod. 2	Mod. 1	Mod. 2
Valence ratings	.198	.190	.001	.001			.001	.001
Activation ratings	.127	.145	.001	.001[a]			.001	.001
Global intensity (I_{glob})	.084	.104	.006	.004[b]	.024	(.053)[c]	.025	(.059)
Emotion intensity (I_{emot})								
- happy	.129	.122	.001	.001	.007	.011	.005	.008
- peaceful	.090	.081	.004	.012	.046	(.053)	.009	.011
Emotion specificity (I_{spec})								
- happy	.115	.107	.001	.003	.046	(.057)	.002	.003

Note: Gender and preference for classical music (model 1), and Absorption scores (model 2) were used to predict mean valence and activation ratings, global intensity of induced emotions, and intensity and specificity of the five emotions. Only significant variables and p-values are shown. Absorption scores are omitted because they never reached significance. [a]Model 2 slightly better than model 1 because of contribution of Absorption score ($p = .086$); [b]model 2 slightly better than model 1 because of contribution of Absorption score ($p = .079$); [c]non-significant p-values $< .10$ are represented in parentheses.

Table 10 reveals that preference for classical music most strongly predicts the intensity of emotional responses. In some cases, gender is also a significant predictor, while absorption never contributes significantly to the explained variance. Note that significant coefficients were obtained for positive emotions only. In general, the predictive power of the included personality variables was low and did not exceed 20 percent of explained variance.

FAMILIARITY

There were large differences in levels of participants' familiarity with the music across pieces and emotion categories. On average, music pieces were familiar to 20 percent of participants. Individual familiarity ranged from 1 to 50 percent. The five pieces in the 'happy' category were most familiar (32%), followed by 'peace' (28%), 'sadness' (21%), 'anger' (11%) and 'fear' (6%). The unbalanced distribution of familiarity ratings across categories precludes the analysis of influences of this variable across the entire sample of excerpts. For example, greater valence values of familiar pieces could simply result from the fact that 'happiness' and 'peace' excerpts were relatively more familiar to the participants, whereas 'anger' and 'fear' pieces were by and large unknown. Within-category correlation analysis of familiarity was found to be inadequate due to an insufficient number of pieces per category. Moreover, it would remain unclear to what extent such correlations reflected participants' actual emotional experience, or rather the popularity of some emotionally potent music stimuli.

Discussion

One goal of this study was to investigate the specificity and intensity of induced emotions during music listening on the basis of emotion, valence and arousal ratings. In addition, influences of individual differences on these ratings were examined, namely absorption trait, musical training and preference.

Twenty-five excerpts from the western classical instrumental music repertoire, which represented five intended emotion categories, were selected and presented to listeners individually. The central hypothesis was that valence and arousal ratings are associated with emotion categories as predicted by the circumplex model (Russell, 1980).

It was observed that the majority of pre-selected pieces did induce corresponding emotions. Analyses of individual pieces suggest positive relationships between intended and felt emotions in pieces from all emotion categories. Two selections induced an emotion that was different from the intended one, whereas responses to three pieces could not be attributed to one specific emotion at the group level. Moreover, there were wide differences in the intensity of emotion induction across categories. Emotion induction was found to be strongest for pieces in the 'happiness' and 'peace' categories, and was found to be weaker in the remaining categories. It should be noted, however, that more ambiguous excerpts were found in the 'anger' and 'fear' categories, which could explain lower mean intensity values. In sum, these patterns of results support the first hypothesis, in that a predominantly positive relationship between intended and felt emotion was observed for this specific stimulus set.

Valence and arousal ratings differentiated emotion categories. Specifically, 'happy' pieces were characterized by high valence/high arousal, whereas 'anger' and 'fear' pieces elicited low valence/high arousal responses. Excerpts in the 'peace' category were found to induce high valence/low arousal. 'Sadness' induced similar feelings as the 'peace' category, although the former should induce negative valence according to the circumplex model. The weaker differentiation between 'anger' and 'fear' as well as between 'sadness' and 'peace', which has been frequently documented in previous studies, was reflected in small distances in the centroid cluster analysis. A similar pattern emerged when the analysis was based solely on those cases in which only one single emotion was induced. Increasing levels of intensity were associated with differentiated changes in arousal and valence. With respect to 'peace' and 'sadness', diverging patterns of changes were observed: increasing levels of 'peace' concurred with increasing valence, whereas increasing levels of 'sadness' concurred with greater levels of arousal without affecting valence. The overall similarity between 'sadness' and 'peace' categories with respect to their attributed valences and arousal levels is still surprising. In particular, 'sad' excerpts were rated far more positively than would be expected from the circumplex model. However, with respect to music, 'sad' pieces, particularly from the genre of classical instrumental repertoire, are often found aesthetically pleasing and inducing intensely positive emotions (Balkwill and Thompson, 1999; Kreutz et al., 2003; Panksepp, 1995; Panksepp and Bernatzky, 2001).

Concerning the second goal of this study, which addressed individual differences, it should be noted that no attempt was made to manipulate the selected variables systematically. Nevertheless, the results suggest some firm influences on emotion induction with music.

Preference for classical music clearly enhanced both intensity and specificity of induced emotions. The individual's long-term commitment to classical music is apparently important if this genre of music is used for emotion induction, and, in a similar vein, mood induction (Västfjäll, 2001–02). This finding seems to be of some importance, as previous research could not establish, for example, a general relationship between musical preference and music aptitude (Abeles and Chung, 1996: 318).

Therefore, a careful screening of participants' preferences is mandatory in order to maximize emotional responses, at least at a subjective level.

Second, a number of correlations were found between absorption scores and emotional responses. Absorption was significantly correlated with induced activation and global intensity of emotions and, to a lesser degree, with the intensity of sadness and happiness. However, the absorption trait failed to add predictive power in the regression analyses when entered in addition to preference. These findings support results from the study by Snodgrass and Lynn (1989), who also used classical music but applied different inventories to measure absorption. These authors observed that 'high hypnotizable' participants reported more absorption than 'low hypnotizable' participants. Thus, our results provide further evidence that absorption is associated with emotional experiences during music listening. It should be noted, however, that the mode of presentation in this study – namely the short duration of the musical pieces, the interruption by the rating phases and the continuous change between different emotions – may not have permitted strong absorption in the music. In the future, the relationships between individual differences in absorption and emotional experience should be assessed under conditions that give participants more time to become fully absorbed in the music, as seems mandatory for other emotional responses such as 'chills' (Panksepp, 1995). Thus, the 'what' and the 'how' of musical stimulation should be optimized in further studies to induce deeper absorption and stronger emotions in the listeners.

Third, in this study, the influence of musical background was investigated by forming two groups with low and high expertise. Contrary to the hypothesis, the latter group showed no stronger responses to the music, with the exception of activation ratings. Against expectations, it was the low expertise group that reported stronger emotions in general and for all emotions except peacefulness. One possible explanation for this result could be the tendency of more experienced listeners to focus more on technical and motor aspects of the performance than on emotional expression. There were too few professional musicians in our sample, however, adequately to differentiate musical expertise.

How do these findings relate to emotion induction with visual materials, e.g. the International Affective Picture System (IAPS; Bradley and Lang, 2000)? In these studies, picture stimuli are typically classified as 'appetitive', 'aversive', or 'neutral'. 'Neutral' stimuli are characterized by low arousal, whereas 'appetitive' or 'aversive' stimuli are characterized by high arousal level. These characteristics result in a V-shaped distribution of IAPS picture stimuli in the circumplex diagram. Our results reveal similar patterns of 'appetitive' and 'aversive' highly arousing music stimuli, which induce 'happiness', 'anger' and 'fear', respectively. In contrast to the IAPS results, however, low arousing music stimuli from the 'peace' and 'sad' categories induced positive feelings. Thus, 'peace' and 'happy' categories are different in arousal, but similar in valence. This configuration of emotion categories in the music domain allows the independent variation of valence and arousal dimensions. Comparing 'appetitive' or 'aversive' stimuli with 'neutral' stimuli in the IAPS always concurs with variations in both dimensions (Bradley and Lang, 2000). In the present study, the excerpts in the 'peace' category differ in one single dimension when compared with the 'happy' category (arousal) or with the 'neutral' category (valence).

It should be noted that in a considerable number of cases emotional responses were at best marginal. These 'neutral' responses were found to be located in the centre of the circumplex diagram and tended to move toward the low valence/low arousal quadrants with decreasing intensity.

When valence and arousal were considered, low values in both dimensions simultaneously amounted to 12 percent of total responses. Thus the stimuli induced a wide range of responses across the entire circumplex space. One possible explanation for this phenomenon is that participants were bored by the music in these instances. A preliminary analysis revealed that low valence/low arousal ratings were predominantly elicited by pieces in the 'fear' category. Considering the high average arousal induced by this category, individual differences in response patterns must be assumed, which will be analyzed in depth elsewhere.

In this study, participants' familiarity with the musical materials was conceptualized as a stimulus attribute at the group level. It simply reflects the observation as to whether a piece of music is known to the listeners. Due to the unequal distribution of familiarity across emotion categories, it is not possible to undertake a detailed analysis of the influence of this variable on emotion ratings. However, it may well be that less familiarity with excerpts, particularly from the 'fear' and 'anger' categories, influences the intensity of music listening. This imposes some limitations on the interpretation of our data.

In a similar vein, it should be noted that self-selected music often elicits stronger emotions than pre-selected materials. Pre-selected music excerpts may not accommodate the individual musical biography, i.e. individual preferences and expectations. However, pre-selection must be seen as a prerequisite for developing standardized sets of experimental music stimuli, in analogy to the visual domain.

To sum up, the present study confirms and extends previous work on the induction of emotion during music listening (Gabrielsson, 2001–02; Västfjäll, 2001–02). The stimuli chosen for this experiment have proved suitable for the induction of basic emotions as assessed by subjective ratings. Further studies are necessary to validate the present responses using other samples including physiological measures. One intriguing question for the guidance of future research is the neural representation of musically induced basic emotions (Kreutz et al., 2003). The present stimulus set seems to be well suited for this endeavour since it covers a wide spectrum of emotional as well as valence and arousal responses. The ambiguity of some of the stimuli may be advantageous in the assessment of individual differences, i.e. physically identical stimuli may well induce widely diverging emotions. Finally, the complex influences of individual differences in personality and musical background on musically induced emotions were observed. In particular, the strong influence of preference raises the question as to what extent the stimuli should be selected in accordance with participants' tastes. Popular styles such as pop and rock music appear to be more appropriate for samples of young adults. Liking for classical music is thus a prerequisite for securing strong emotional responses.

REFERENCES

Abeles, H.F. and Chung, J.W. (1996) 'Responses to Music', in D. Hodges (ed.) *Handbook of Music Psychology*, pp. 285–342. San Antonio: IMR Press.

Alpert, J.I. and Alpert, M.I. (1989) 'Background Music as an Influence in Consumer Mood and Advertising Responses', *Advances in Consumer Research* 16: 485–91.

Balkwill, L. and Thompson, W.F. (1999) 'A Cross-cultural Investigation of the Perception of Emotion in Music: Psychophysical and Cultural Cues', *Music Perception* 17: 43–64.

Bigand, E., Vieillard, S., Madurell, F., Marozeau, J. and Dacquet, A. (2005) 'Multidimensional Scaling of Emotional Responses to Music: The Effect of Musical Expertise and of the Duration of the Excerpts', *Cognition and Emotion* 19(8): 1113–39.

Blood, A.J. and Zatorre, R.J. (2001) 'Intensely Pleasurable Responses to Music Correlate with Activity in Brain Regions Implicated in Reward and Emotion', *Proceedings of the National Advances of Sciences* 98(20): 11818–23.

Bradley, M.M. and Lang, P.J. (2000) 'Affective Reactions to Acoustic Stimuli', *Psychophysiology* 37: 204–15.

Brennis, N.C. (1970) 'Mood Differential Responses to Music as Reported by Secondary Music and Non-music Students from Different Socioeconomic Groups', PhD dissertation, University of Miami, USA.

Brown, S., Martinez, M. and Parsons, L. (2004) 'Passive Music Listening Spontaneously Engages Limbic and Paralimbic Systems', *NeuroReport* 15(13): 2033–7.

Campbell, I.G. (1942) 'Basal Emotional Patterns Expressible in Music', *The American Journal of Psychology* 55(1): 1–17.

Carlton, L. and MacDonald, R.A.R. (2003) 'An Investigation of the Effects of Music on Thematic Apperception Test (TAT) Interpretations', *Musicae Scientiae* Special Issue: 9–30.

Clynes, M. (1977) *Sentics: The Touch of Emotions*. New York: Doubleday/Anchor.

Dalla Bella, S., Peretz, I., Rousseau, L. and Gosselin, N. (2001) 'A Developmental Study of the Affective Value of Tempo and Mode in Music', *Cognition* 80: B1–B10.

Davidson, J.W., Howe, M.J.A. and Sloboda, J.A. (1997) 'Environmental Factors in the Development of Musical Skill over the Life Span', in D.J. Hargreaves and A.C. North (eds) *The Social Psychology of Music*, pp. 188–206. Oxford: Oxford University Press.

De Vries, B. (1991) 'Assessment of the Affective Response to Music with Clynes's Sentograph', *Psychology of Music* 19(2): 46–64.

Everitt, B.S., Landau, S. and Leese, M. (2001) *Cluster Analysis* (4th edition). London: Arnold.

Gabrielsson, A. (1993) 'On Strong Experiences of Music', in K.-E. Behne, G. Kleinen and H. de la Motte-Haber (eds) *Musikpsychologie. Jahrbuch der Deutschen Gesellschaft fuer Musikpsychologie, Band 10*, pp. 114–25. Wilhemshaven: Florian Noetzel Verlag.

Gabrielsson, A. (2001–02) 'Perceived Emotion and Felt Emotion: Same or Different?' *Musicae Scientiae* Special Issue: 123–49.

Gabrielsson, A. and Lindström, E. (2001) 'The Influence of Musical Structure on Emotional Expression', in N.P. Juslin, and J.A. Sloboda (eds) *Music and Emotion: Theory and Research*, pp. 223–48. Oxford: Oxford University Press.

Gregory, A.H. and Varney, N. (1996) 'Cross-cultural Comparison in the Affective Response to Music', *Psychology of Music* 24(1): 47–52.

Gupta, U. and Gupta, B.S. (2005) 'Psychophysiological Responsivity to Indian Instrumental Music', *Psychology of Music* 33(4): 363–72.

Hevner, K. (1935) 'The Affective Character of the Major and Minor Modes in Music', *American Journal of Psychology* 47: 103–18.

Hills, P. and Argyle, M. (1998) 'Musical and Religious Experiences and their Relationship to Happiness', *Personality and Individual Differences* 25: 91–102.

Jürgens, U. (2002) 'Neural Pathways Underlying Vocal Control', *Neuroscience and Biobehavioral Reviews* 26(2): 235–58.

Juslin, N.P. (2001) 'Communicating Emotion in Music Performance: A Review and a Theoretical Framework', in N.P. Juslin and J.A. Sloboda (eds) *Music and Emotion: Theory and Research*, pp. 309–40. Oxford: Oxford University Press.

Juslin, N.P. and Laukka, P. (2003) 'Communication of Emotions in Vocal Expression and Music Performance: Different Channels, Same Code?' *Psychological Bulletin* 129(5): 770–814.
Juslin, P.N., Friberg, A. and Bresin, R. (2001–02) 'Toward a Computational Model of Expression in Performance: The GERM Model', *Musicae Scientiae* Special Issue: 63–122.
Juslin, N.P. and Sloboda, J.A. (2001) *Music and Emotion. Theory and Research*. New York: Oxford University Press.
Kemp, A. (1997) 'Individual Differences in Musical Behavior', in D.J. Hargreaves and A.C. North (eds) *The Social Psychology of Music*, pp. 25–45. Oxford: Oxford University Press.
Khalfa, S., Peretz, I., Blondin, J.-P. and Manon, R. (2002) 'Event-related Skin Conductance to Musical Emotions in Humans', *Neuroscience Letters* 328(2): 145–9.
Kivy, P. (1990) *Music Alone: Philosophical Reflections on the Purely Musical Experience*. Ithaca, NY: Cornell University Press.
Koelsch, S., Schröger, E. and Tervaniemi, M. (1999) 'Superior Pre-attentive Auditory Processing in Musicians', *Neuroreport* 10(6): 1309–13.
Koelsch, S., Gunter, T., Friederici, A.D. and Schröger, E. (2000) 'Brain Indices of Music Processing: "Nonmusicians" are Musical', *Journal of Cognitive Neuroscience* 12(3): 520–41.
Kreutz, G. (2002) '"Jede Sehnsucht hat eine Melodie." Basisemotionen in der Musik und im Alltag' ('Every longing carries a melody': Basic emotions in music and everyday life), *Musikpsychologie* 16: 66–83.
Kreutz, G., Bongard, S. and von Jussis, J. (2002) 'Kardiovaskuläre Wirkungen beim Musikhören. Zur Bedeutung von musikalischer Expertise und Emotion' ['Cardiovascular responses to music listening: On the influences of musical expertise and emotion'], *Musicae Scientiae* 6(2): 257–78.
Kreutz, G., Russ, M.O., Bongard, S. and Lanfermann, H. (2003) 'Zerebrale Korrelate des Musikhörens. Eine fMRT-Studie zur Wirkung "fröhlicher" und "trauriger" klassischer Musik' ['Cerebral correlation of music listening. An fMRI-Study on the Effects of "happy" and "sad" classical music'], *Nervenheilkunde* 6: 51–6.
Kreutz, G., Ott, U. and Vaitl, D. (2006) 'Spezifität des emotionalen Ausdrucks klassischer Musikstücke: Ergebnisse einer Befragung von Musikstudenten' ['Specificity of the emotional expression of classical music: Results of a group study'], *Musikpsychologie* 18: 104–24.
Krumhansl, C.L. (1997) 'An Exploratory Study of Musical Emotions and Psychophysiology', *Canadian Journal of Experimental Psychology* 51: 336–52.
Lewis, B.E. and Schmidt, C.P. (1991) 'Listeners' Responses to Music as a Function of Personality Type', *Journal of Research in Music Education* 39: 311–21.
Lindström, E., Juslin, P.N., Bresin, R. and Williamon, A. (2002) '"Expressivity Comes from within your Soul": A Questionnaire Study of Music Students' Perspectives on Expressivity', *Research Studies in Music Education* 20: 23–47.
McNamara, L. and Ballard, M.E. (1999) 'Resting Arousal, Sensation Seeking, and Musical Preference', *Genetic, Social and General Psychological Monographs* 125: 229–50.
Miller, M.M. and Strongman, K.T. (2002) 'The Emotional Effects of Music on Religious Experience: A Study of the Pentecostal-Charismatic Style of Music and Worship', *Psychology of Music* 30(1): 8–27.
Nair, D.G., Large, E.W., Steinberg, F. and Kelso, J.A.S. (2002) 'Perceiving Emotion in Expressive Piano Performance: A Functional-MRI Study', in C. Stevens, D. Burnham, G. McPherson, E. Schubert, J. Renwick (eds) *Proceedings of the 7th International Conference on Music and Cognition*, pp. 627–30. Adelaide: Causal Productions.
Nater, U.M., Krebs, M. and Ehlert, U. (2005) 'Sensation Seeking, Music Preference, and Psychophysiological Reactivity to Music' *Musicae Scientiae* 9(2): 224–38.

North, A.C. and Hargreaves, D.J. (1997) 'Liking, Arousal Potential, and the Emotions Expressed by Music', *Scandinavian Journal of Psychology* 38: 45–53.

Nyklicek, I., Thayer, J.F. and van Doornen, L.J.P. (1997) 'Cardiorespiratory Differentiation of Musically-induced Emotions', *Journal of Psychophysiology* 11: 304–21.

Ortony, A. and Turner, T.J. (1990) 'What's Basic about Basic Emotions?', *Psychological Review* 97: 315–31.

Panksepp, J. (1995) 'The Emotional Sources of "Chills' Induced by Music', *Music Perception* 13: 171–207.

Panksepp, J. and Bernatzky, G. (2001) 'Emotional Sounds and the Brain: The Neuro-affective Foundations of Musical Appreciation', *Behavioral Processes* 60: 133–55.

Peretz, I., Gagnon, L. and Bouchard, B. (1998) 'Music and Emotion: Perceptual Determinants, Immediacy and Isolation after Brain Damage', *Cognition* 68: 111–41.

Ritossa, D.A. and Rikkard, N.S. (2004) 'The Relative Utility of "Pleasantness" and "Liking" Dimensions in Predicting the Emotions Expressed by Music', *Psychology of Music* 32: 5–22.

Ritz, T. and Dahme, B. (1995) 'Die Absorption-Skala: Konzeptuelle Aspekte, psychometrische Kennwerte und Dimensionalität einer deutschsprachigen Adaption' (The absorption scale: Conceptual aspects, psychometric evaluation, and dimensionality of a German adaptation), *Diagnostica* 41: 53–61.

Robazza, C., Macaluso, C. and d'Urso, V. (1994) 'Emotional Reactions to Music by Gender, Age, and Expertise', *Perceptual and Motor Skills* 79: 939–44.

Russell, J.A. (1980) 'A Circumplex Model of Affect', *Journal of Personality and Social Psychology* 39: 1161–78.

Scherer, K.R. and Oshinsky, J. (1977) 'Cue Utilization in Emotion Attribution from Auditory Stimuli', *Motivation and Emotion* 1: 331–46.

Sloboda, J.A. (1991) 'Music Structure and Emotional Response: Some Empirical Findings', *Psychology of Music* 19(2): 110–20.

Sloboda, J.A. and Juslin, N.P. (2001) 'Psychological Perspectives on Music and Emotion', in N.P. Juslin and J.A. Sloboda (eds) *Music and Emotion: Theory and Research*, pp. 71–104. Oxford: Oxford University Press.

Sloboda, J.A and Lehmann, A.C. (2001) 'Tracking Performance Correlates of Changes in Perceived Intensity of Emotion During Different Interpretations of a Chopin Piano Prelude', *Music Perception* 19(1): 87–120.

Sloboda, J.A., O'Neill, S.A. and Ivaldi, I. (2001) 'Functions of Music in Everyday Life: An Exploratory Study using the Experience Sampling Method', *Musicae Scientiae* 5(1): 9–32.

Smith, J. (1999) 'Movie Music as Moving Music: Emotion, Cognition, and the Film Score', in C. Plantinga and G.M. Smith (eds) *Passionate Views: Film, Cognition, and Emotion*, pp. 146–67. Baltimore, MD: Johns Hopkins University Press.

Snodgrass, M. and Lynn, S.J. (1989) 'Music Absorption and Hypnotizability', *International Journal for Clinical Experimental Hypnosis* 37: 41–54.

Sopchak, A.L. (1955) 'Individual Differences in Responses to Music', *Psychology Monograph* 69(11): 1–20.

Tellegen, A. and Atkinson, G. (1974) 'Openness to Absorbing and Self-altering Experiences ('Absorption'), a Trait Related to Hypnotic Susceptibility', *Journal of Abnormal Psychology* 83: 268–77.

Thaut, M.H. and Davis, W.B. (1993) 'The Influence of Subject-Selected versus Experimenter-Chosen Music on Affect, Anxiety and Relaxation', *Journal of Music Therapy* 30: 210–23.

Thayer, J. and Faith, M. (2001) 'A Dynamic Systems Model of Musically Induced Emotions: Physiological and Self-Report Evidence', *Annals of the New York Academy of Science* 930: 452–56.
Västfjäll, D. (2001–02) 'A Review of the Musical Mood Induction Procedure', *Musicae Scientiae* Special Issue: 173–212.
Wallach, M.A. and Greenberg, C. (1960) 'Personality Functions of Symbolic Sexual Arousal to Music', *Psychological Monographs: General and Applied* 74(7): whole issue.
Webster, G.D. and Weir, C.G. (2005) 'Emotional Responses to Music: Interactive Effects of Mode, Texture, and Tempo', *Motivation and Emotion* 29(1): 19–39.
Wild, T.C., Kuiken, D. and Schopflocher, D. (1995) 'The Role of Absorption in Experiential Involvement', *Journal of Personality and Social Psychology* 69(3): 569–79.
Winold, A.C. (1963) 'The Effects of Changes in Harmonic Tension upon Listener Response', PhD dissertation, Indiana University, USA.

Appendix:

	Emotion	Composer	Title	Period
1	Happiness	Joseph Haydn	Symphony No. 70, D major	Classical
2	Happiness	Johann Strauss II	*Tausendundeine Nacht*	Romantic
3	Happiness	Georges Bizet	Carmen Suite No. 1, 2nd movement: Aragonaise. Allego vivo	Romantic
4	Happiness	Richard Strauss	Divertimento Op. 86, 2nd movement: Musette de Choisy	Romantic
5	Happiness	Joseph Haydn	String quartet No. 10, B major, Op. 2, No. 6, 3rd movement: Scherzo: Presto	Classical
6	Sadness	Tomaso Albinoni	*Adagio*, G minor	Baroque
7	Sadness	Gabriel Fauré	*Elegie*, Op. 24, C minor, for violoncello and orchestra	Impressionism
8	Sadness	John Dowland	*Dances from Lachrimae: Semper Dowland Semper Dolens*, 'Goe Nightly Cares'	Renaissance
9	Sadness	Wolfgang Amadeus Mozart	Piano concerto no. 21, KV 467, C major, 2nd movement: Andante	Classical
10	Sadness	Franz Schubert	String quartet no. 14, D minor, D. 810, 'Der Tod und das Mädchen', 2nd movement: Andante con moto	Romantic
11	Anger	Gustav Holst	*The Planets*, Op. 32, 'Mars – The Bringer of War'	Modern
12	Anger	Edgar Varese	*Arcana* for full orchestra	Modern
13	Anger	Dimitri Shostakovich	Symphony no. 10, E minor, Op. 14: Allegro	Modern

(*Continued*)

Appendix (Continued)

14	Anger	Modest Mussorgsky	*Quadri ad una mostra* (Pictures at an exhibition), 'La capanna della Baba-Yaga su zampe di pollo'	Romantic
15	Anger	Darius Milhaud	Symphonies nos 1 and 2, Très vif	Modern
16	Peace	Max Bruch	Concerto for violin, no. 1, 2nd movement: Adagio	Modern
17	Peace	Arthur Foote	'Capricorn' concerto, 1. 'Air'	Modern
18	Peace	Pietro Mascagni	*Cavalleria rusticana*, 'intermezzo'	Baroque
19	Peace	Wolfgang Amadeus Mozart	Piano concerto, no. 21, C major, KV 467, 2nd movement: Andante	Classical
20	Peace	Wolfgang Amadeus Mozart	Andante for flute and orchestra, C major, KV 315	Classical
21	Fear	Edgar Varese	*Amériques* for full orchestra	Modern
22	Fear	Edgar Varese	*Arcana* for full orchestra	Modern
23	Fear	Luigi Nono	*Ricorda cosa ti hanno fatto in Auschwitz* for voices and tape	Modern
24	Fear	Olivier Messiaen	*Danse de la fureur, pour les sept trompettes*	Modern
25	Fear	Olivier Messiaen	*Fouilis d'arcs-en-ciel, pour l'Ange qui annonce la fin du Temps*	Modern

GUNTER KREUTZ has been a Research Fellow in the Research Centre for the Vocational Training of Musicians, part of the Centre for Excellence in Teaching and Learning at the Royal Northern College of Music, since April 2006. He received his PhD from the University of Bremen in 1996 and his formal qualification to teach at German universities (*Habilitation*) from the Goethe-University Frankfurt in 2004. His research interests include music psychology and specifically the psychophysiology of music perception and performance in amateurs and professionals.
Address: Royal Northern College of Music, 124 Oxford Road, Manchester, M13 9RD, UK. [email: gunter.kreutz@rncm.ac.uk]

ULRICH OTT studied psychology at the Goethe-University in Frankfurt, Germany. From 1998 to 2005, he worked on a project entitled 'Altered States of Consciousness' at the Liebig-University, Giessen, with a research focus on states of absorption induced by rhyth-mical body movements and music. Since 2005 he has been a staff scientist at the Bender Institute of Neuroimaging (BION), University of Giessen. The BION is an external research unit of the Institute for Frontier Areas of Psychology and Mental Health in Freiburg. A detailed curriculum vitae can be found at his homepage: http://www.bion.de
Address: Bender Institute of Neuroimaging, University of Giessen, Otto-Behaghel-Str. 10H, 35394 Giessen, Germany. [email: ott@bion.de]

DANIEL TEICHMANN was engaged in this study as a student of psychology. His diploma thesis treated questions of selection and presentation of musical stimuli for emotion induction in a neuroimaging setting.
Address: Bender Institute of Neuroimaging, University of Giessen, Otto-Behaghel-Str. 10H, 35394 Giessen, Germany. [email: dan_pond@gmx.de]

PATRICK OSAWA was engaged in this study as a student of psychology. His diploma thesis investigated individual differences in response to emotional musical stimuli, especially differences in musical experience and the disposition to become absorbed.
Address: Bender Institute of Neuroimaging, University of Giessen, Otto-Behaghel-Str. 10H, 35394 Giessen, Germany. [email: stratman2000@freenet.de]

DIETER VAITL headed the department of Clinical and Physiological Psychology at the University of Giessen, Germany, from 1976–2005. Since 2000, he has been Director of the Bender Institute of Neuroimaging (BION) at the University of Giessen. The BION is an external research unit of the Institute for Frontier Areas of Psychology and Mental Health in Freiburg (www.igpp.de), which is also headed by him. Since 1988, he has been Director of the Institute of Psychobiology and Behavioral Medicine at the University of Giessen. His research is focused on cardiovascular psychophysiology, affective neuroscience, biofeedback and clinical applications of neuroimaging. A detailed curriculum vitae and description of his research fields can be found at his homepage: http://www.bion.de.
Address: Bender Institute of Neuroimaging, University of Giessen, Otto-Behaghel-Str. 10H, 35394 Giessen, Germany. [email: Dieter.Vaitl@psychol.uni-giessen.de]