In: Music Education
Editor: Joao Hermida and Mariana Ferrero
ISBN: 978-1-60876-655-0

Chapter 1

MUSIC INDUCED EMOTIONS: SOME CURRENT ISSUES AND CROSS-MODAL COMPARISONS

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ABSTRACT

The potential of music to communicate emotions is part of our everyday experience. Music psychologists have distinguished between *emotion perception,* which refers to the perception of emotions expressed by music without evoking affective responses in the listeners, and *emotion induction*, which refers to listeners' affective response to music. Here, we focus on emotion induction. The first part briefly discusses recent empirical evidence and theoretical reflections on i) the nature of musical emotions, ii) emotion models in relation to music, iii) the influence of factors like familiarity, culture, gender, personality, expertise and contextual features on listeners' emotional experience, and iv) the link between emotion and aesthetics. The second part concerns itself with musical emotions and the central nervous system and discusses recent findings of brain areas involved in emotional processing of music, issues related to cerebral asymmetry, and the link between emotion and cognition in these processes. In this context, the question of whether emotions evoked by music are similar or different compared to emotions evoked by other sensory modalities has been of substantial interest to music researchers. Therefore, we extensively address this issue and report on current cross-modal affective priming studies. Automatic affective responses to stimuli are essentially relevant for subsequent cognitive, emotional and behavioural reactions: emotions induced by music crucially influence the (emotional) processing of pictures, facial expressions, films, and words. We propose that cross-modal priming studies provide a promising alternative to conventional approaches in order to better understand the nature of musical emotions.

"Music produces a kind of pleasure which human nature cannot do without."

Confucius (551-479 BC)

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1. INTRODUCTION

Music is as fundamentally part of a culture as painting and drawing, and a culture that lacks music has yet to be discovered (Juslin and Sloboda 2001). In an evolutionary context, research and theories about the origins of music have recently received widespread attention (Wallin, Merker et al. 1999; Mithen 2005; Cross and Morely 2009), but how do our daily life experiences with music relate to possible explanations of the origins, characteristics and functions of music? In other words, what are the underlying psychological human needs that may explain the universal relevance of music? In *Politics* (Book VIII), Aristotle attributed a natural 'sweetness' to music, and proposed that men listen to music to get pleasure and relax from exhausting work (Saunders 1992). This reference to the close relationship between music and emotional experience was later echoed in Thomas More's *Utopia* (1516), a classic literature describing an ideal society. The Utopians are described as having pleasures that either relate to the mind or the body. Music is regarded as a pleasure that belongs to the body:

> There is another kind of pleasure that arises neither from our receiving what the body requires, nor its being relieved when overcharged, and yet, by a secret unseen virtue, affects the senses, raises the passions, and strikes the mind with generous impressions – this is, the pleasure that arises from music. (More, Logan et al. 2002, p.72)

These classical philosophical ideas are still valid, and considerable evidence based on empirical research has been accumulated suggesting an important relationship between subjectively experienced pleasure and music; this evidence has come from diverse fields including cognitive and aesthetic neuroscience (Blood and Zatorre 2001; Wallenstein 2008), consumer behaviour (Wicke 1990; Frith 2004; Longhurst 2007), popular music research and music sociology (Hargreaves and North 1999; DeNora 2000; Rentfrow and Gosling 2003; North, Hargreaves et al. 2004; Juslin, Liljeström et al. 2008). There is no doubt that music plays an essential part in our daily lives (Juslin and Laukka 2004). Music elicits a wide spectrum of emotional experience (Hays and Minichiello 2005; Laukka 2007; Saarikallio and Erkkilä 2007), and is routinely used for mood and emotion regulation (Rickard 2004). Taken together, all these findings either explicitly or implicitly point to music's powerful influence on bodily states. If this was not the case, people would not spend billions annually on music (IFPI 2006).

In this chapter, we will first address several current issues in emotion research on music by focusing on induced emotions. In the second part, we will discuss the brain responses related to music induced emotions. We will further report on the possible link between cognition and emotion in processing music. Finally, we will present the latest evidence of cross-modal processing of music-induced emotions.

2. CURRENT ISSUES IN RESEARCH ON MUSIC AND EMOTION

Empirical research on music and emotion has gained an increasing interest over the last two decades, which is reflected in the first dedicated volume on music and emotion edited by Juslin and Sloboda (2001) and its forthcoming sequel (Juslin and Sloboda 2009), which comprises around 1000 pages and is the longest book ever published in the field of music psychology. This growing interest in musical emotions is partly due to the general boost in emotion research in fields outside music and to the rapid advancement in neuroimaging techniques. Considering the fact that the field of music psychology is relatively young compared to other fields of psychology, the current interest in musical emotions may also be explained by the natural progress to move towards questions related to music and emotions after the initial predominance of research on music cognition in the 1980-90s. Thus, it is not surprising that in the field of music and emotion many issues still need to be resolved. Some of these issues result primarily from comparisons to emotional processing in other domains, while others may be more related to music-specific characteristics.

2.1. Music-Induced Mood and Emotion – Same or Different?

Researchers generally distinguish between several types of measures of emotions (Abeles and Chung 1996), but there is currently no general agreement on the basic terminology of emotional states. For example, Abeles and Chung (1996) differentiate between preferences, affective and mood/emotional responses. McMullen (1996) interprets aesthetic behaviour by distinguishing between preference/hedonic tone, mood/feeling tone, and aesthetic response. Further, Scherer (2004) describes a set of types of affective states, including preferences, mood, utilitarian emotions, aesthetic emotions, interpersonal stances, attitudes and personality traits. More recently, Juslin and Västfjäll (2008) propose to differentiate between affect, emotions, mood, feelings and preferences.

Music is a powerful means of inducing specific mood states (Pignatiello, Camp et al. 1986; Storbeck and Clore 2005). But is music-induced mood same or different from emotions induced by music? Despite the lack of general agreement on the different terms and definitions used in music and emotion research as discussed earlier, most of the researchers do agree that moods refer to “affective states that feature a lower felt intensity than emotions, that do not have a clear object, and that last much longer than emotions (several hours to days)”, and that emotions refer to “relatively intense affective responses that usually involve a number of sub-components – subjective feeling, physiological arousal, expression, action tendency, and regulation – which last minutes to a few hours” (Juslin and Västfjäll 2008, p. 561). Although there could be some overlap between music-induced mood and emotion, the time scale of operation is important while making a relative distinction between the two: music-induced mood lasts longer, whereas music-induced emotion is rather short-lived.

The length of the musical stimulus under investigation and its relation to the mood-emotion differentiation constitutes another related issue. For example, Khalfa and colleagues (2002) argue that only short musical excerpts of several seconds are suitable for the study of musical emotions, whereas studies using longer stimuli investigate mood rather than emotion (Pignatiello, Camp et al. 1986; Storbeck and Clore 2005). Music is a continuous stream of musical events and can thus be considered as a sequence of auditory events that people perceive and respond to (Steinbeis, Koelsch et al. 2006). Music is dynamic and changes over time, and physiological responses, such as changes in skin conductance, heart rate, are elicited by both short (Guhn, Hamm et al. 2007) and long (Kivy 1989; Juslin and Laukka 2004; Scherer 2004; Konecni, Brown et al. 2008; Zentner, Grandjean et al. 2008) musical excerpts. Therefore, the argument that only short musical excerpts elicit real emotions is not entirely convincing. We suggest that an operational differentiation between emotion and mood can be better made at the level of the duration of the evoked state, which does not necessarily depend on the length of the stimulus.

2.2. Are Musical Emotions ‘Real’?

In spite of the ubiquitous fact that many people report to experience emotions as response to music in their daily lives, the question of whether music can induce ‘real’ emotions, that is, emotions elicited by auditory and visual objects/events/situations that constitute an essential part of our daily lives, has been debated for ages and so far lacked consensus (Kivy 1989; Juslin and Laukka 2004; Scherer 2004; Juslin and Västfjäll 2008; Konecni 2008; Konecni, Brown et al. 2008; Zentner, Grandjean et al. 2008). For instance, some argue that music, being iconic or representative of emotion, cannot induce real emotions but only express them (Kivy 1990). This position has been coined as ‘cognitivist’ by Kivy. Others state that the combined empirical evidence for emotion induction by music is substantial (Gabrielsson 2002; Juslin and Laukka 2004; Kallinen and Ravaja 2006; Schubert 2007; Evans and Schubert 2008; Zentner, Grandjean et al. 2008; Roy, Mailhot et al. 2009), suggesting that musical emotions are similar to real emotions elicited by other sensory stimuli. The latter position has been coined as ‘emotivist’.

2.3. Perceived and Felt Emotion – Same or Different?

There is increasing evidence pointing towards a difference between emotion perception or *perceived emotion* (the emotion that listeners perceive in the music) and emotion induction or *felt emotion* (the emotion that listeners feel in themselves when listening to the music) (Kallinen and Ravaja 2006; Kreutz and Lotze 2007; Evans and Schubert 2008; Peretz in press). This differentiation can be introduced in the discussion of experiential and physiological responses to music, based on the task the researchers asked the participants to accomplish. Therefore, one is advised to critically distinguish between studies that focus on either emotion perception or induction. Unfortunately, current research efforts on music and emotions do not strictly make that distinction (Gabrielsson and Juslin 1996; Juslin 2000; Sloboda 2000; Sloboda and Lehmann 2001; Juslin and Laukka 2003; Peretz in press). In addition, research in music psychology has primarily concentrated on emotion perception instead of emotion induction in the last decade, often in the context of music performance research and emotion expression (Peretz 2001).

However, emotion induction by music is currently receiving more attention in the field. For example, induced musical emotions may be conceptualized to depend on a multiplicatory fashion on structural features (referring to the music), performance features, listener features and contextual features (Scherer and Zentner 2001). The relative weigthing of these features and their interaction in producing an emotional state is still unclear. Additionally, it can be hypothesized that the relative importance of these features may vary across musical styles (e.g., classical versus contemporary music, instrumental versus vocal music) and change over the course of a single piece because emotion induction in music is a temporal phenomenon. Many of the issues addressed in this section refer directly or indirectly to this model of induction rules.

The question of how music evokes emotions has recently been addressed by Juslin and Västfjäll (2008) who propose six mechanisms through which listening to music can induce emotions: (i) brain stem reflexes, (ii) evaluative conditioning, (iii) emotional contagion, (iv) visual imagery, (v) episodic memory, and (vi) musical expectancy. The authors argue that these mechanisms differ in terms of "information focus, ontogenetic development, key brain regions, cultural impact, induction speed, degree of volitional influence, modularity, and dependence on musical structure" (Juslin and Västfjäll 2008, p. 559). Thus, researchers are advised to control for the underlying mechanisms of emotion induction when designing experiments. Their hypotheses gained widespread attention, partly because they oppose the assumption that musical emotions are mostly based on a cognitive appraisal mechanism. They also stand in contrast to the emotion-inducing mechanisms suggested by Scherer (2004), who differentiates between central route production (appraisal, memory and empathy) and peripheral route production (proprioceptive feedback, facilitating the expression of pre-existing emotions). Clearly, the question of how musical emotions are induced is still open and needs further investigation. Additionally, it is still unclear how experimenters can control for the mechanisms of emotion induction in an experimental setting.

2.4. Are Musical Emotions Similar to Other Emotions?

An important issue is whether emotions elicited by music are same or different from emotions elicited in other domains (Scherer and Zentner 2008). What type of emotions can music elicit in listeners? For example, Juslin and Västfjäll (2008) suggest that music induces emotions that are qualitatively very similar to emotions evoked by other types of stimuli. Moreover, they also draw our attention to one very specific feature of musical emotions that sets them apart from everyday emotions:

> What is unique about musical emotions is not the underlying mechanisms or the emotions they evoke, but rather the fact that music – unlike most other stimuli for our emotions in everyday life – is often intentionally designed to induce emotions, using whatever means available. (p. 572)

Conversely, Scherer (2004) clearly differentiates between 'utilitarian' and 'aesthetic' emotions that are part of our daily lives, arguing that utilitarian emotions comprise a range of basic emotions, such as fear and sadness that have "major functions in the adaptation and adjustment of individuals to events that have important consequences for their well being" (p. 241), while aesthetic emotions are largely defined by the absence of cognitive, goal-oriented appraisal but based on other appraisal mechanisms:

> [A]n aesthetic experience is one that is not triggered by concerns with the relevance of a perception to my bodily needs, my social values, or my current goals or plans, nor with how well I can cope with the situation, but one where the appreciation of the instrinsic qualities of a piece of visual art or a piece of music is of paramount importance. (Scherer, 2004, p. 242)

Specifically, Scherer and Zentner (2008) suggest that music can evoke both types of emotion, but more frequently aesthetic emotions than utilitarian ones.

In a similar vein, Frijda and Sundararajan (2007) propose to differentiate between 'coarse' and 'refined' emotions. Inspired by Confucian philosophy and Chinese poetry, they argue that coarse and refined emotions represent two specific modes of all possible emotions rather than two emotion categories comprising a subset of emotions:

> Coarse emotions differ from emotions that are more felt than acted upon [i.e. refined emotions], and thus do not obviously manisfest themselves in overt behaviours like attack, embrace, or flight, may not show very pronounced physiological upset, are often about complex events or subtle event aspects; and are easily done justice by common emotion labels. (p. 227)

They extensively elaborate the idea of refined emotions by discussing detachment, restraint, second-order experience and self-reflexive awareness as characteristics of this type of emotional state.

The theoretical approaches presented above may fail to address the important issue of the role of the 'producer' of a work of art or music in the emotional experience of it, even in cases in which s/he is not physically present. In other words, to what degree is the physical presence of the producer (artist, writer, musician) relevant to the emotional experience of a recipient in response to a work of art (painting, poem, piece of music)? We argue that it is crucial to point out that the dissociation between the producer of a work of art and the work of art itself at the time of its experience may be wider in the visual arts, printed poetry and literature than in music. From an evolutionary and socio-historical perspective, music is a social phenomenon (Merriam 1964) experienced in real-time, since before the invention of recording systems music could only be experienced by being in presence of the people making music. Therefore, one can argue that there could be an intrinsic coupling between the musician and the music itself in vocal and instrumental music experience, even in the physical absence of the singers and musicians when listening to music. In live performances of vocal music, the presence of the singer is presumably even more relevant to the emotional experience of listeners than in the experience of instrumental music. Such a strong coupling between the musician and the produced music is probably also part of the experience of theatre, opera and popular music, but less so in the visual arts and literature, except for public readings. This crucial difference, which is directly related to the temporal experience of art, could lead to a differentiation of emotions evoked by 'temporal arts' and 'static arts'. Thus, it can be assumed that emotions induced by temporal arts may be different from those induced by static arts because the producer is physically more 'present' in these art forms (and still nowadays physically real in live-concert settings) and as such has an effect on the emotional experience evoked by the work of art. Admittedly, nowadays music recordings are a very common way of transmitting music and evoking emotional responses, but the musician and the music were not originally dissociated. Consequently, our biological system may process emotions related to temporal arts and static arts differently. Musical emotions may thus be more similar to utilitarian or coarse emotions because musicians could usually also evoke utilitarian or coarse emotions in other everyday contexts without making music. In addition, the currently perceived difference between music as art experienced for its own sake and music as part of everyday social activities was probably less clear many thousand years ago (Cross and Woodruff 2009).

However, we consider these categorizations as premature and question whether this differentiation between utilitarian and aesthetic emotions or coarse and refined emotions will lead to a better understanding of the issue to what degree musical emotions are differently or similarly processed and experienced compared to emotions outside the domain of music. Consequently, we argue that these questions can be better resolved by comparing various physiological and subjective emotional responses across domains in a first step. The current state of research on music and emotion is clearly not advanced enough in order to make an a priori definition of different types of emotions, especially because at present the general scientific community does not even agree on a definition of the term 'emotion' (Izard 2007) or the question of whether a discrete or dimensional approach to emotion is more appropriate (Mauss and Robinson 2009). However, most researchers would agree on a componential approach to emotion, which implies that coordinated changes in different components (physiological arousal, motor expression, behaviour preparation, subjective feeling) define an emotion episode (Scherer 2004). To test whether musical emotions are indeed 'special', one could follow a systematic approach and empirically investigate each of these components separately by using a wide range of measures and making comparisons across domains.

As stated above, behaviour is also an essential component of an emotional response to a stimulus (Frijda 1988; Gross 2007). Activation of the action or motor network has recently been found in response to beautiful and ugly paintings (Kawabata and Zeki 2004); according to the componentional approach to emotion, this could reflect behaviour preparation and approach/withdrawal tendencies. In consequence, one could argue that aesthetic experience is characterized by behavioural responses which are typical features of utilitarian emotions, which makes differences between the two potential emotion categories less apparent. Importantly, motor areas have also be found to be activated in neuroimaging studies on music and emotion (Blood and Zatorre 2001). Additionally, studies using facial electromyography have shown that emotions induced by music (Witvliet and Vrana 2007; Khalfa, Roy et al. 2008; Roy, Mailhot et al. 2009) lead to specific activities of the facial muscles including corrugator supercilii (active while frowning) and zygomaticus major (active while smiling), indicating valence-related behavioural responses commonly induced in other domains than music (Larsen, Norris et al. 2003).

2.5. Models of Musical Emotion

Traditionally, psychologists and neuroscientists interested in musical emotions use and adapt approaches that are common in the general field of emotion research (Juslin and Sloboda 2001; Kreutz, Ott et al. 2008), including basic emotion models (Ekman 1999; Izard 2007), dimensional models (Russell 1980; Posner, Russell et al. 2005) and the prototype approach (Shaver, Schwartz et al. 1987). Basic emotion models, i.e. discrete emotion theory, assume that a specific emotion, such as fear, is characterized by a specific neural network, whereas dimensional models argue that every specific emotion is based on two or more common overlapping neurophysiological systems. The prototype approach is based on the assumption that language shapes how people conceptualize and categorize information. The membership in a particular category is determined by the resemblance to prototypical exemplars. These contrasting models have gained wide acceptance in general, although some researchers suggest that these models need to be refined (Schimmack and Grob 2000; Frijda and Sundararajan 2007).

In music research, the use of the basic emotion model and the dimensional model has been widespread, although some researchers have provided arguments for the development of music-specific emotion models (Scherer 2004; Collier 2007; Konecni 2008). Recently, Zentner and colleagues (2008) developed a 9-dimensional model of musical emotions by collecting intensity ratings for emotion descriptors from participants that liked to listen to a specific musical style, either in a private or in a concert setting. By using factor analysis, they found categories of predominantly positive emotion terms that can be used to describe one's subjective feeling in response to music, going beyond emotions terms that are generally used in basic emotion models or dimensional models. Most importantly, the researchers argue that these feelings may not be unique to music, but that aesthetic experiences in everyday life are common: "It is possible that emotions felt in response to music are just one example of a much larger category of emotions relating to aesthetically appraised day-to-day objects, situations, and experiences, which, as a whole, occupy much space in human lives" (Zentner, Grandjean et al. 2008, p. 515). We support the view that many day-to-day objects, situations and experiences can elicit emotions that are related to aesthetic experience, but is this experienced pleasure of a different quality than the one experienced in other reward situations (food, sex, monetary rewards, and drugs)? Or may the difference be rather a quantitative one, that is, different degrees of emotional intensity varying along a continuum between utilitarian and aesthetic emotions? The answer to these questions is likely to be crucial, particularly when discussing the differentiation between utilitarian and aesthetic emotions in the context of music research (Scherer 2004).

2.6. Aesthetic Experience and Emotion

Neuroaesthetics, primarily focusing on the cognition of visual arts, is a young promising interdisciplinary field that may offer some answers to the intriguing questions on emotion and music mentioned in the previous sections (Skov and Vartanian 2009). As already stated in the introduction to this chapter, music experience is clearly related to some kind of pleasure, thus the link between aesthetics and emotions elicted by art and music is clear-cut. Many acknowledged philosophers have been pondering on issues referring to aesthetic experience in the past. For example, the British philosopher Anthony Earl of Shaftesbury (Earl of Shaftesbury 1964/1711) differentiated between 'disinterested' and 'interested' enjoyment. The former refers to enjoyment for its own sake, the latter to enjoyment of anticipated benefits. Francis Hutcheson, a student of Shaftesbury, further developed these ideas and suggested a sharp division between everyday and aesthetic experience (Hutcheson 1725). Proposing a more psychological theory of aesthetic experience, he argued for a special 'taste faculty' and disinterested pleasure based on a specific criterion for beauty. However, this idea was later rejected by Immanuel Kant (Kant 1914/1790) who argued that there is only one underlying cognitive faculty which is involved in both the experience of ordinary objects and the searching for satisfying structures in objects that lead to the experience of pleasure. Like Shaftesbury, Kant defended the notion of 'disinterested pleasure' ('interesseloses Wohlgefallen'). Arthur Schopenhauer (Schopenhauer 1969/1818) further developed Kant's ideas and gradually a theory of aesthetic experience emerged:

> According to Schopenhauer, everyday consciousness is in the service of the will, but if the intellect can temporarily subdue the will, a state of disinterested detachment can be achieved in which aesthetic qualities can be suitably contemplated." (Cupchik, Vartanian et al. 2009, p. 84)

In the 20th century, Beardsley (1958; 1966) developed a theory of aesthetic experience as a specific psychological process that is characterized by a slight detachment of affect and a certain degree of freedom from concerns referring to past and future events. As such this theory is in the tradition of 'disinterest'; however, it does not entail a faculty that produces disinterest, which instead is rather seen as an emergent property of the aesthetic experience.

Neuroscientists interested in the visual arts have developed paradigms that may be useful to research on music and emotion, thus shedding light on the question of whether musical emotions are similar or different compared to emotions elicited in other domains. Some recent findings suggest that the underlying brain networks involved in the perception of art overlap with those involved in the perception of other reward-based stimuli (Vartanian and Goel 2004) or social and moral cues (Jacobsen, Schubotz et al. 2006). Other findings, however, show that the perception of beauty in art may be based on a neural network specific to aesthetic appreciation (Cela-Conde, Marty et al. 2004).

More recently, researchers investigated the effect of context on aesthetic experience (Kirk, Skov et al. 2009). It can be assumed that an object or image is differently perceived in a daily-life context than in an art gallery, and that context and intentional perception may provide the underlying basis for the difference between aesthetic and utilitarian emotions. Indeed, the researchers found that the responses of the prefrontal and orbitofrontal cortices that are involved in the processing of aesthetic judgement are biased by people's expectations about the hedonic value of a stimulus according to the context. Further support for the influence of context on the neural processing of aesthetic experience in the visual domain has been recently provided (Di Dio, Macaluso et al. 2007; Höfel and Jacobsen 2007; Cupchik, Vartanian et al. 2009). Therefore, it can be reasonably concluded that aesthetic appreciation in the context of visual arts clearly requires intention. But is this also the case for music? Music is also often appreciated while being engaged in other activities (Juslin and Laukka 2004). Apparently, the issue of how the appreciation of music differs from the appreciation of other art forms is still unresolved and currently rarely addressed among music psychologists and cognitive neuroscientists. We argue that emotions induced by music should not only be compared to emotions elicited in other domains in general, but also specifically to emotions elicited by other arts forms.

2.7. Role of Social Context in Experiencing Music

Music is experienced in many different ways in our daily lives (DeNora 2000), and the level of consciousness or intentional listening may vary to a large extent in these settings. For example, music can be experienced as background music in shops or films, while working or driving in a car, or in a church or live-concert setting. It would be a challenge to develop real-life paradigms that create these different contextual settings in a restricted laboratory environment and to compare the emotional responses between different contexts. Distraction tasks (incidental versus focused listening) provide one possibility to investigate the effect of context/intention/consciousness on the aesthetic appreciation of music. Indeed, behavioural evidence suggests that the relationship between familiarity and liking ratings is influenced by incidental versus focused listening to music (Szpunar, Schellenberg et al. 2004; Tan, Spackman et al. 2006; Schellenberg, Peretz et al. 2008). In a similar fashion, the importance of social context on emotion perception has been discussed in a recent ethnomusicological study (Baraldi 2009). In a Gypsy community in Transylvania, the very same melodies are played at weddings and funerals. It was found that the aesthetic meaning depends on the social context. Furthermore, music is often experienced in groups and the emotional responses of group members may have an impact on people's emotional response (Egermann, Grewe et al. 2009). In summary, empirical evidence suggests that music and its social context may significantly modulate emotions induced by music.

2.8. Role of Expertise

Another current issue is the question of whether aesthetic and emotional experience may be affected by expertise. For example, expertise with architecture has been found to modulate cognitive processing of architectural stimuli, and most importantly, also the response in reward-related brain areas (Kirk, Skov et al. 2009). It remains to be seen whether musicians' responses in reward-related areas also differ from those of non-musicians. Studies comparing musicians and non-musicians' physiological responses to music are rare, but the sparse evidence (Bhattacharya and Petsche 2001; Kreutz, Bongard et al. 2002; Steinbeis, Koelsch et al. 2006) suggests that expertise may affect physiological processing of emotions in subtle ways. Empirical evidence for the effect of musical training on subjective experience of musical emotions points to different directions. For example, musical expertise has been found to resolve the inverted U-relationship between liking and complexity (Orr and Ohlsson 2005), often regarded as one of the core elements of experimental aesthetics (Berlyne 1971). Conversely, Rawlings and Leow (2008) investigated the effect of personality traits on the experience of musical emotions, and their results indicate that musicians rated relaxing music as more cheerful and pleasant than non-musicians, but they were also more familiar with the musical excerpts, which makes it difficult to differentiate between the effects of familiarity and musical training. Overall, musical training seems to have a minimal effect on emotional experience, which is in line with the argument that non-musicians can generally be considered as experienced listeners (Bigand and Poulin-Charronnat 2006), which particularly holds true for affective responses to music:

> Musical activities would probably have disappeared from all human societes if listeners were unable to confer (or perceive) an affective value to musical stimuli. Being able to apprehend the emotional quality of musical stimuli is so important that it might be at the heart of all musical abilities. (Bigand & Poulin-Charronnat, 2006, p. 117)

While investigating implicit responses to music, Bigand and colleagues (2005) showed that there is a high consistency between musicians and non-musicians when grouping musical excerpts of similar emotional quality based on their felt emotion. Furthermore, the length of the excerpts (30s versus 1s) did not largely affect the number of groups or their content. To conclude, the current empirical evidence suggests that musicians and non-musicians may differ in their physiologial responses to music, but the effects of musical training on subjective experience are less than conclusive. In addition, the current studies vary widely in terms of methodology and the range of stimuli used, which makes comparisons between them rather difficult. Thus, it remains an open issue which aspects of emotional response to music are modulated by expertise.

2.9. Role of Familiarity

The issue of musical expertise is closely linked to the issue of familiarity and its role in emotion induction as well as to related issues of individual differences. Researchers usually control for familiarity with the musical stimuli by questionnaires on the participants' musical background and/or ratings of familiarity for each individual excerpt used in an experiment. For instance, Zentner, Grandjean and Scherer (2008) controlled for familiarity with the musical styles in their study on the development of a music-specific model of emotion. It is a well-established fact that in general there is a positive association between familiarity and liking (Zajonc 1968; Kunst-Wilson and Zajonc 1980; Hargreaves 1984; Peretz, Gaudreau et al. 1998; Zajonc 2001), although this relationship can be modulated by context and expertise as already mentioned earlier (Orr and Ohlsson 2005). Moreover, it has been previously suggested that familiarity should be considered in models of musical emotions (Ritossa and Rickard 2004), and others suggested that preference (liking) needs to be considered as well (Kreutz, Ott et al. 2008). In a study combining qualitative and quantitative methods, Parncutt and Marin (2006) collected emotion terms in response to unfamiliar music and found that 20th-century art music is especially associated with negative feelings and emotion categories. Listeners disliked unfamiliar music, and subjective verbal responses were grouped by other participants into categories such as anger, chaos, madness, aggression and fear. Therefore, music is clearly able to elicit negative emotions, especially in listeners that are unfamiliar with a musical style. Consequently, it can be argued that by controlling for preference only one part of the wide spectrum of emotion terms is covered in the musical emotion model proposed by Zentner and colleagues (2008). A 'complete' model of feelings induced by music should thus include emotion terms that refer to negative emotions (negative valence, high- and low-arousing) that can be elicited under certain circumstances and thus address the issue of familiarity. In other words, one can argue that deliberate exposure to a familiar musical style may explain the large amount of positive emotion terms reported by Zentner and colleagues (2008). Surely, people mostly gain pleasure and positive emotions from their interaction with music, arts, or aesthetic experiences linked to natural scenes, but at the same time people cannot always choose to expose themselves to music that they are familiar with and/or like to listen to, even in a context that is primarily meant to elicit pleasure. For example, in an art gallery, there are paintings or sculptures that do not necessarily provide pleasure to the visitors though they have chosen to go there in order to experience some kind of pleasure. Similarly, people are often exposed to music in diverse contexts or situations, and not every one of them is under direct control of the listeners. Thus, it can be assumed that negative emotions are induced in listeners who do not appreciate a musical piece, a specific performance of a piece, or a piece of art in general although they deliberately expose themselves to it. All these examples point again to the intrinsic qualities of the visual or auditory events that are the focus of interest in aesthetic experience.

We propose that the effect of familiarity on emotion induction can be discussed on different levels within and across cultures, ranging from issues related to familiarity with a musical style in general to repeated listening of the same piece and to the effect of repetition of musical material within a piece on emotional experience. An example of a study on the latter aspect of familiarity was conducted by McAdams and colleagues (2004), who used an unfamiliar contemporary piece, specifically composed for research purposes, to investigate induced emotions and the effect of repetition of musical material. During the performance in a live-concert setting, listeners rated continuously their experienced familiarity and the emotional force of the musical material. Emotional force ratings were found to decrease in repeated musical material, suggesting that it is important to consider effects of familiarity at different levels of the musical material (within a piece, at the level of a piece, specific performance of a piece, musical style, and musical system).

2.10. Role of Culture

In light of the above evidence, it could be argued that issues related to (un)familiarity and evoked emotions by music can broadly be addressed from two perspectives: i) (un)familiarity with musical pieces or styles within one's familiar culture, and ii) (un)familiarity with music coming from different cultures. In other words, listeners may be unfamiliar with music coming from their own culture but familiar with music from a different culture. This differentiation is important because through enculturation to a musical tonal system culture-specific brain structures are created (Hannon and Trainor 2007; Wong, Perrachione et al. 2009), which can be compared to the learning of a first language. For example, the implicit knowledge of harmony is specific to Western cultures and has been found to be important in emotional experience (Steinbeis, Koelsch et al. 2006), and the same holds true for the role of mode in emotion perception (Juslin and Laukka 2004; Khalfa, Roy et al. 2008). Findings of a cross-cultural study on Arab music extend the importance of tonality in emotional experience to musical cultures outside the Western world (Ayari and McAdams 2003).

Balkwill and Thompson (1999) proposed a theory of cross-cultural emotion recognition: culture-specific and universal cues interact in the process of musical emotion recognition. Listeners unfamiliar with a musical system primarily base their judgements on musical cues such as tempo, melodic/rhythmic complexity and pitch range, whereas members of a specific culture additionally rely on the conventions of a tonal system (Balkwill, Thompson et al. 2004). This theory has gained some attention by other researchers (Krumhansl, Toivanen et al. 2000; Morrison, Demorest et al. 2003; Eerola, Himberg et al. 2006; Nan, Knösche et al. 2006). Very recently, further evidence for the universal recognition of happy, sad and scary/fearful music and the positive relationship between perceived consonance and pleasantness has been found in both African and Western listeners (Fritz, Jentschke et al. 2009). However, these studies focused on emotion perception and cross-cultural studies on emotion induction are rather rare. Marin and colleagues (2007) found that Western and Persian listeners' experience of induced emotions by Western tonal, atonal, and Persian music is largely influenced by familiarity with a musical system. Nevertheless, findings of current cross-cultural studies on physiological responses to music do not offer converging evidence

(Kemal Arikan, Devrim et al. 1999; Morrison, Demorest et al. 2003; Nan, Knösche et al. 2006; Han and Northoff 2008; Wong, Perrachione et al. 2009). Intensive collaborations between ethnomusicologists and music psychologists may help to resolve these conflicting reports.

2.11. Role of Gender

In the Western world, females are often portrayed as being more emotional than males (Fischer and Manstead 2000), but do these stereotypes also hold true for emotions induced by music? If yes, how can these differences be explained? Research outside the domain of music has shown that gender affects emotional responses in many subtle ways, which has been partly attributed to biological and sociocultural factors (Baron-Cohen, Knickmeyer et al. 2005). Females are more likely to develop affective disorders (Sachs-Ericsson and Ciarlo 2000), but they also report more happiness and joy (Brody 1996). In addition, females are more emotionally expressive than males (Brody and Hall 2000); however, this is not necessarily linked to stronger emotional experiences (Kring and Gordon 1998). Specifically, Bradley and colleagues (2001) showed that females are more reactive to unpleasant pictures, both in physiological measures and in self-reports. Likewise, Wager and colleagues (2003) reported in a meta-analysis of neuroimaging studies on emotion that males showed more lateralization of emotional activity, whereas females were characterized by more brain stem activation. More recently, other studies reported gender-related differences in diverse emotional paradigms including both auditory and visual domains (Besson, Magne et al. 2002; Canli, Desmond et al. 2002; Pietrzak, Laird et al. 2002; Wildgruber, Pihan et al. 2002; Royet, Plailly et al. 2003; Cahill, Uncapher et al. 2004; Bourne 2005; Schienle, Schäfer et al. 2005; Scholten, Aleman et al. 2005).

Studies have reported gender effects of emotional processing in music research as well. For example, Altenmüller and colleagues (2002) detected in their EEG study on the valence-lateralisation hypothesis that the emotion-specific asymmetry was characterized by larger areas in females than in males. Moreover, females reported more often dislike for the negative musical stimuli. Koelsch and colleagues (2003) conducted a meta-analysis of previous EEG studies on the processing of musical syntax, which is related to musical expectancy and thus possibly to emotional experience as well. Their results indicated that an electrophysiological correlate (early right anterior negativity, ERAN) of music-syntactic processing is generated bilaterally in females, and it has a right hemispheric predominance in males (Koelsch, Maess et al. 2003). Similar to adults, gender effects in music-syntactic processing were also revealed in children. Boys showed a lateralization of the ERAN to the left, which could not be found in girls (Koelsch, Grossmann et al. 2003). Nater and colleagues (2006) invited participants to listen to Renaissance and Heavy Metal music while measuring psychophysiological responses (heart rate, finger temperature and skin conductance level). They also collected self-reports and endocrine measures. Results demonstrated that females showed a stronger physiological response to the unpleasant Heavy Metal music than males, which is in line with research in domains outside music (Kring and Gordon 1998; Bradley, Codispoti et al. 2001). Females differed from males in their emotional response regarding skin conductance level and finger temperature, but not in their heart rate patterns and endocrine measures. Interestingly, gender did not affect self-reports, suggesting a dissociation between psychological and physiological response patterns. Recently, Flores-Gutiérrez and colleagues (2009) were interested in gender effects in responses to pleasant and unpleasant music by Bach, Mahler and Prodromidès. They analysed EEG coherence, a measure of functional connectivity, and also recorded self-reports of emotional experience. Results indicated that gender differences occur in the patterns of functional coupling between brain regions within the alpha frequency range. Gender did not affect subjective reports of emotions, which is in line with the findings by Nater and colleagues (2006).

Researchers have recently also made efforts to explain gender differences in relation to music. Kreutz and colleagues (2008) applied Baron-Cohen's empathizer-systemizer (E-S) theory to music. 'Empathizing' is characterised as the ability to respond to other's feeling states, whereas 'systemizing' is characterised as the ability to respond to regularities of objects and events. Neurobiological differences between females and males may explain these different cognitive styles that are typical of females (empathizing) and males (systemizing). For example, males' brains are generally larger, but their corpora collosa are smaller. In males, these anatomical differences could lead to an increase of local connectivity and a decrease of inter-hemispheric connectivity. Although there are some novel aspects in E-S theory, it has not remained uncriticised (Nettle 2007). In order to test their idea of applying E-S theory to music, Kreutz and colleagues (2008) collected online responses to questionnaires from a large sample and found significant effects of gender for music empathizing and systemizing. In summary, gender effects have been described by a wide range of studies on musical emotions. Explanations for gender differences will also have to account for a possible dissociation between psychological and neuro(physiological) responses to music (Johnsen, Tranel et al. 2009), which makes the discussion of gender effects more complex. Therefore, future research designs need to include a wider range of background measures, to incorporate social factors, and to focus on specific musical styles.

2.12. Role of Personality

Research on individual differences in emotion processing is quite scarce because researchers prefer to compare groups rather than individuals in their analyses by either balancing or ignoring effects of individual differences (Hamann and Canli 2004). However, individual differences may play a large role in emotional experiences and several studies have indicated that research on induced musical emotions should control for personality traits, dispositional affect, and genotype. Unfortunately this has rarely been the case so far. Gerra and colleagues (1998) investigated the relationship between personality traits, temperament and emotional responses to 30 minutes of techno-music or classical music using a wide range of neuroendocrine measures, physiological measures and self-reports. The findings suggest that certain neuroendocrine measures correlate with personality traits and temperament. Moreover, musical preferences have been found to be associated with personality traits (Rentfrow and Gosling 2003; Schwartz and Fouts 2003). These results may help to explain why people like the music they do, which goes beyond the analysis of the musical stimuli under investigation. A recent study assessed whether neuroticism is related to perceived similarity of another person and whether the familiarity of a context (background music) influences this relationship (Moss, Garivaldis et al. 2007). Participants with higher levels of neuroticism were more likely to perceive another person as dissimilar to themselves on the scales of openness and extraversion. This perceived dissimilarity in extraversion was particularly pronounced when the participants rated music as familiar. Studies like this highlight the complexity involved in the subtle effects that music may have on individual's experiences in multi-modal settings of daily lives.

3. Emotions Induced by Music and the Central Nervous System

In the last decade, research on the neural correlates of musical emotions has gained increasing interest in the field. Lesion and neuroimaging studies have primarily focused on emotion recognition in music (Peretz in press), mainly following approaches related to theories of categorical (Gosselin, Peretz et al. 2007) or dimensional models of emotion (Khalfa, Schon et al. 2005). Only recently, several studies investigated the neural pathways of emotion induction using various neuroimaging techniques and paradigms. Reseachers have generally been interested in issues related to valence and brain lateralization (Altenmüller, Schurmann et al. 2002; Flores-Gutierrez, Diaz et al. 2007), the processing of emotional peak experiences or chill sensations (Blood and Zatorre 2001), specific musical features and their relation to emotion induction (Steinbeis, Koelsch et al. 2006) as well as general brain activation while listening to music (Brown, Martinez et al. 2004; Mitterschiffthaler, Fu et al. 2007). Empirical evidence for effects of long-term musical training on emotional neural processing is sparse (Koelsch 2005; Pallesen, Brattico et al. 2005).

Since the number of studies is rather limited, and the results are not always pointing in the same direction, the discussion of a neurobiological account of emotions induced by music is currently complex, challenging and also controversial. Furthermore, a direct comparison and generalization of the limited findings is problematic for various reasons as follows. First, the musical stimuli used in the current studies vary along several dimensions. For example, they range from highly controlled and artificial music (Blood, Zatorre et al. 1999) to ecologically valid and natural (Flores-Gutierrez, Diaz et al. 2007). In addition, they often vary in duration, from relatively short (Altenmüller, Schurmann et al. 2002) to long (Sammler, Grigutsch et al. 2007). The length of a musical stimulus plays an important role in the differentiation between emotion and mood induction (Juslin and Sloboda 2001). Moreover, some researchers equalize for loudness across musical stimuli of different emotional quality (Altenmüller, Schurmann et al. 2002), whereas others make the participants adjust the volume (Flores-Gutiérrez, Díaz et al. 2009). Loudness and tempo are related to arousal (Schubert 2004), and an equalization of loudness may thus tremendously decrease external validity of the findings. In some studies, stylistic variation is kept to a minimum (Baumgartner, Lutz et al. 2006), whereas others include a wide range of styles (Altenmüller, Schurmann et al. 2002), potentially introducing confounds related to timbre and the number of instruments involved. Second, researchers either ignore the effect of familiarity on emotional response to music (Schmidt and Trainor 2001) or try to control for it (Koelsch, Fritz et al. 2006). Third, definitions of common terms used in musical emotion research may vary across studies. For instance, the term 'valence', which is related to dimensional models of emotions (Russell 1980), is defined as approach vs. withdrawal (Field, Martinez et al. 1998), positive vs. negative (Field, Martinez et al. 1998), pleasant vs. unpleasant (Koelsch, Fritz et al. 2006) consonance vs. dissonance (Blood, Zatorre et al. 1999; Koelsch, Fritz et al. 2006), happy vs. sad (Schmidt and Trainor 2001) and even as liking vs. dislike (Altenmüller, Schurmann et al. 2002). Although positive correlations between these numerous definitions are possible, these definitions of valence are not necessarily identical. For instance, dissonant and negative music can be liked by some individuals and therefore considered as pleasant (Schubert 1996). Therefore, sad music is probably rather related to approach than to withdrawal. Finally, gender affects the neural processing of emotions induced by music (see Sect. 2.11), which is often not sufficiently controlled for. While it is true that some of the issues mentioned above are due to the different research questions asked, the specific designs of the study and the types of measurement employed, others can be resolved, for example, by not treating music as a uni-dimensional stimulus and by better controlling for listeners' features. Equally important, the diversity of methods, musical stimuli and listeners' features has led to a diversity of reliability, making comparisons difficult, if not invalid. Consequently, interdisciplinary collaboration between music theorists, musicologists and neuroscientists may provide a fruitful basis for research that seeks to link specific musical features to emotion induction. The limited present findings should be regarded as a starting point for more refined, hypothesis-driven research that also aims at replicating previous results in this young field.

3.1. Brain Areas Associated with Emotions Induced by Music

What brain areas have been associated with emotions induced by music so far? In order to answer this question effectively, we have to rely on those neuroimaging techniques like functional magnetic resonance imaging (fMRI) or positron emission topography (PET) which offer superior spatial resolution than other commonly available techniques like EEG. One of the pioneering neuroimaging studies on emotion induction by music was conducted by Blood and Zatorre (2001), who investigated the neural substrates of intensely pleasurable emotional experiences known as chills or shivers down the spine. Musicians were listening to self-selected classical music that reliably elicited chills in them. PET was used in order to measure regional cerebral blood flow (rCBF); chill intensity ratings were positively correlated with activations of reward circuitry (left dorsomedial midbrain, insula, orbitofrontal cortex) and negatively correlated with activations of fear circuitry (amygdala, left hippocampus, ventral medial prefrontal ratings). This study clearly showed that music recruits neural systems of both positive (reward) and negative (fear) emotions similar to those recruited by biologically relevant stimuli. Further, these results led to the intriguing suggestion that pleasant emotion is not just due to an activation of positive emotional circuitry but also due to an inhibition of negative emotional circuitry. Moreover, activation of the hippocampus in music processing may be explained by emotion induction mechanisms such as episodic memory and visual imagery as well as by nostalgia, an emotion which is commonly induced by music (Zentner, Grandjean et al. 2008).

Similarly, Brown and colleagues (2004), also using PET, had non-musicians listening to unfamiliar but pleasant music. Increased rCBF was found in the temporal lobe and several limbic and paralimbic areas, specifically in the cingulate gyrus, the affective division of the anterior cingulate cortex, retrosplenial cortex, hippocampus, anterior insula, and nucleus accumbens. Activation was overall stronger in the left hemisphere, supporting the frontal activation/valence emotion model (Davidson, Schwartz et al. 1979; Davidson 1993). It needs to be stated that increase of rCBF in the temporal pole, the orbitofrontal cortex, and the superior frontal gyrus in response to positively valenced stimuli was also observed in the visual, general auditory and olfactory domains (Royet, Zald et al. 2000).

Another study by Koelsch and colleagues (2006) examined the neural correlates of the processing of pleasant and unpleasant music by using fMRI. They used original and acoustically manipulated (pitch-shifted) musical excerpts. The manipulation of the stimuli was meant to induce unpleasantness while controlling for melodic contour, dynamics and rhythmical structure. Although this manipulation of musical excerpts may guarantee strict control over musical features, its ecological validity could be limited. Compared to pleasant music, unpleasant stimuli activated the amygdala, the hippocampus, the parahippocampal gyri and the temporal lobes, and compared to unpleasant music, pleasant music activated the Heschl gyrus, anterior superior insula, and Rolandic operculum. The amygdala has been found to be activated during the recognition of emotional vocalizations (Morris, Scott et al. 1999; Sander and Scheich 2001), and patients with resections of the amygdala have impaired recognition of scary music in films (Gosselin, Peretz et al. 2005; Gosselin, Peretz et al. 2007) or tend to perceive unpleasant music as more pleasant (Gottselig 2000). Interestingly, Koelsch and colleagues (2006) also reported that amygdala activations were higher in the second half of the musical excerpts as compared to the first half, thus providing a first account on the neural correlates of temporal dynamics of emotion. The activation observed in the Rolandic operculum is worth mentioning as this region has been found to be active in overt and covert singing (Jeffries, Fritz et al. 2003), in processing of intonation contour of spoken sentences (Meyer, Steinhauer et al. 2004), and during mere listening to sentences that are related to actions. Therefore, the Rolandic operculum is an important node in the mirror-neuron network (Tettamanti, Buccino et al. 2005), which led Molnar-Szakacs and Overy (2006) to suggest that

> [M]usic, like language, involves an intimate coupling between the perception and production of hierarchically organized sequential information, the structure of which has the ability to communicate meaning and emotion. We propose that these aspects of musical experience may be mediated by the human mirror neuron system. (p. 235)

More recently, Mitterschiffthaler and colleagues (2007) used fMRI to investigate the neural response to happy, sad and neutral music. At this point it needs to be mentioned how the researchers defined the term ‘neutral’ valence of music because others argue that music cannot be emotionally neutral. In their pre-study, the researchers asked participants to rate their emotional responses on a continuous scale ranging from happy through neutral to sad. Detailed information on the musical excerpts were not provided, which makes it difficult to interpret the results. What the researchers and the participants considered as a neutral emotional response to music could perhaps be referred to as peaceful, or neither happy nor sad. Music-induced happiness was associated with increased activations in the ventral and dorsal striatum, anterior cingulate, parahippocampal gyrus, and auditory association areas. The music-inducing sadness was related with increased activations in the hippocampus/amygdala and auditory association areas, and the neutral music condition with the insula and auditory association areas. The ventral striatum, a dopaminergic region, has previously been associated with positive emotional states and reward processing (Schultz

2000; Blood and Zatorre 2001; Brown, Martinez et al. 2004; Menon and Levitin 2005; Koelsch, Fritz et al. 2006). Activation of the anterior cingulate cortex (ACC) in response to happy music has also been reported by others (Blood and Zatorre 2001; Menon and Levitin 2005). In general, the ACC is important for the control of autonomic arousal, error monitoring, nociception, conflict processing and appetitive behaviour (Vogt 2005). Happy music was also associated with activation of the left parahippocampal gyrus, a brain region previously found to be activated by the processing of spatial scenes and navigation (Epstein and Kanwisher 1998; Rosenbaum, McKinnon et al. 2004), as well as highly context dependent information (Bar and Aminoff 2003). On the other hand, the involvement of the parahippocampal gyrus is often reported during listening to unpleasant music (Koelsch, Fritz et al. 2006). Sadness induced by music was associated with activation of the right hippocampus/amygdala region, whereas activation of the left amygdala was found by Koelsch and colleagues (2006) in the processing of unpleasant music. However, Brown and colleagues (2004) reported amygdala activation for pleasant music, and Blood and Zatorre (2001) showed a negative relationship between chill intensity and hippocampus/amygdala activation. Therefore, the role of the amygdala in the processing of emotions inducted by music is still not fully resolved. An increase in amygdala activity can also be caused by the appraisal and evaluation of salient emotional stimuli, particularly in the processing of sad stimuli (Richardson, Strange et al. 2004). Importantly, this appraisal can happen without conscious awareness (Phelps 2004), which adds important information to the debate on the role of appraisal in the induction of emotions by music (Scherer 2004; Juslin and Västfjäll 2008). A possible asymmetry of amygdala functions for valence and arousal processing was recently examined in patients with drug resistant partial-epilepsis. Intra-cerebral electrodes were implanted (Lanteaume, Khalfa et al. 2007) while skin conductance responses and electromyographic responses of the corrugator supercillii (EMGc) were measured. The researchers stimulated either the right or the left amygdala and asked the patients to verbally report their experienced emotions. Stimulation of the right amygdala led to negative emotion induction, especially to fear and sadness. In contrast, the stimulation of the left amygdala resulted in induced happiness, fear, sadness or anxiety, indicating a left lateralization of positive valence. An increase of EMGc activity was observed for unpleasant emotions, whereas skin conductance responses were larger for pleasant emotions. Future studies will have to examine if these patterns also hold true for music processing.

3.2. Cerebral Asymmetry

The hemispheric specialization hypothesis for emotional valence (Davidson, Schwartz et al. 1979; Heilman 1997) has been extensively investigated in several domains outside music. This hypothesis implies that emotions are organised around approach and avoidance tendencies, and that they are processed dominantly by the left and right hemisphere, respectively. Therefore, asymmetry in frontal activity would reflect emotional valence. In music research, several studies supported this hypothesis. For example, Schmidt and Trainor (2001) conducted an EEG study where participants listened to four orchestral pieces by Bach, Vivaldi, Barber and Prokofiev that varied in valence and intensity. Larger left frontal activity (i.e. lower EEG power in alpha frequency band) was found for pieces that induced happiness and joy, and larger right frontal activity for those inducing fear and sadness, supporting previous findings from other modalities (Fox 1991; Heller 1993). Similarly, Altenmüller and colleagues (2002) presented jazz, rock-pop music, classical music and environmental sounds to adolescents and recorded direct-current EEG. Further support for a significant lateralization effect was found: left temporal activation was increased by positively valenced emotions, whereas a bilateral pattern with preponderance of the right fronto-temporal cortex was related to negatively valenced emotions. Moreover, the results did not differ between the four genres, and the valence-related differences were larger in females. In a more recent study (Tsang, Trainor et al. 2005), tempo and mode, two musical features that are essentially involved in the induction of emotion, were manipulated in musical excerpts by Albinoni, Grieg, Handel, Mozart, Saint-Saëns and Verdi. Changes of both tempo and mode in the happier direction were associated with greater relative left activation, while changes of both tempo and mode in the sadder direction led to greater relative right activation. The valence lateralization model was also investigated by fMRI and by manipulating the tempo and mode of Western classical stimuli (Khalfa, Schon et al. 2005). Contrasting minor versus major mode revealed a larger activation in the posterior cingulate cortex, and in the left orbito- and mid-dorsolateral frontal cortex. Since the minor mode generally conveys sadness, these results do not support the valence lateralization model previously found using EEG. One explanation for this result could be the different brain imaging techniques (EEG vs. fMRI) used in the respective studies, another could be related to the variation in tasks (induction vs. recognition). Interestingly, the investigation of picture processing by fMRI supported the valence lateralization model (Canli, Desmond et al. 1998). The processing of valenced written words was also found to be lateralized (Herrington, Mohanty et al. 2005), whereas emotional prosody processing does not seem to be lateralized in speech (Kotz, Meyer et al. 2003).

3.3. Emotion, Cognition and Event-Related Potentials (ERPs)

While discussing the neural correlates of emotions induced by music, one should consider the close link between cognition and emotion during processing music (Krumhansl 2002; Krumhansl and Agres 2008). Leonhard Meyer (1956), in his seminal contribution, convincingly argued that “listeners have implicit expectations of what will happen in the music and depending on whether these expectations are fulfilled or not, experience relaxation, or tension and suspense” (p. 43).

Musical meaning generated by musical tension-resolution patterns is based on the hierarchical relationship between elements in music, such as chords in Western music (Krumhansl and Kessler 1982). The perceived distance between chords on the circle of fifths mediates stability (Bharucha and Krumhansl 1983): chords that are closer to the established harmonic context are perceived as more stable or final. Harmonic priming paradigms have shown that a single chord can lead to expectation about the subsequent chord (Bharucha and Stoeckig 1986). This type of expectation is related to musical tension and has been extensively studied (Bigand, Parncutt et al. 1996; Krumhansl 1996; Bigand, Madurell et al. 1999). A recent study has investigated the role of harmonic expectancy violations in Bach chorales on the induction of emotion by combining electrophysiological, psychophysiological and subjective measures (Steinbeis, Koelsch et al. 2006). Harmonic unexpectedness led to an increase in tension, subjective emotionality and electrodermal activity. Ratings of tension and emotionality correlated positively with each other. ERP data revealed an early negativity

(EN), which is similar to the early right anterior negativity (ERAN) previously identified in responses to harmonic violations in chord-progression (Koelsch, Gunter et al. 2000; Koelsch and Friederici 2003). The amplitude of the EN was modulated by the degree of unexpectedness. Additionally, a positive ERP component (P3) was found in response to very unexpected harmonies and was interpreted as reflecting stylistic violations of Western music. In contrast to non-musicians, the EN peaked earlier in musicians, who also showed larger amplitudes of the P3 component. In a similar vein, Koelsch and colleagues (2008) re-evaluated fMRI data on unexpected chords in chord sequences and found that irregular chords activated amygdalae bilaterally. One should note that the irregular chords were subjectively perceived as less pleasant than the expected ones. Taken together, these results equivocally support Meyer's theory on the close relationship between syntactic violations of musical expectancy and emotional processing (Koelsch, Fritz et al. 2008).

But syntactic processes and related hierarchies are not necessarily specific to music, and a case in point is the common comparison of syntactic processing in music and language (Koelsch, Gunter et al. 2002). Syntax can generally be defined as a set of rules governing the combination of discrete elements into sequences at multiple hierarchical levels (Jackendoff 2002). However, interdisciplinary research can only succeed if formal similarities and differences between musical and linguistic syntax are carefully considered (Patel 2008). Neuropsychological and neuroimaging studies of the last decade suggest either a dissociation (Peretz 1996) or an overlap of syntactic processing of music and language (Patel, Gibson et al. 1998; Maess, Koelsch et al. 2001; Brown, Martinez et al. 2006). In order to reconcile these conflicting results, Patel (Patel 2003; Patel 2008; Patel 2009) proposed a sharing of neural resources in the processing of linguistic and musical syntax. The 'shared syntactic integration resource hypothesis' implies that there is an overlap in the resource network (activates representations during syntactic processing) but not in the respective representation networks (store long-time syntactic representations). Recent studies have provided behavioural (Fedorenko, Patel et al. 2009; Slevc, Rosenberg et al. 2009) and electrophysiological (Koelsch, Gunter et al. 2005) evidence for this hypothesis. Further evidence was found in 5-year-old children with a specific language impairment, who were also impaired in their music-syntactic processing (Jentschke, Koelsch et al. 2008). Therefore, it can be stated that current neuroscientific findings on syntax processing also suggest that emotions induced by music, specifically those related to (un)expectedness, are only partly based on brain areas that are unique to music processing.

Jackendoff (2009) made the convincing point that "the parallels between language and music can be explored only in the context of a) the differences between them and b) those parallels that are also shared with other cognitive domains" (p. 195). The first part of the statement clearly refers to the nature of music and the question of how music can be defined, the second part refers to aspects that are domain-general, such as recursion, the use of memory, learning processes and social context. Equally important, the need to consider sub-components of music processing in the current discussion on modularity and the brain has been recently highlighted (Peretz 2009). Domain-specificity does not necessarily imply music-, or language-specificity, but it can refer to specific sub-components of processing that are also involved in emotional processing. For example, Kuperberg (2007) reviewed the latest findings on semantic and syntactic processing of language, focusing specifically on the N400 and P600 components. The N400 component was originally found to be sensitive to semantic congruity in sentence processing (Kutas and Hillyard 1980). Importantly, empirical evidence suggests that the N400 and P600 components do not only occur in the processing of auditory stimuli, such as in the processing of environmental sounds (Cummings, Ceponieni et al. 2006), but also in visual processing, like in the processing of faces, pictures or videos (Holcomb and McPherson 1994; West and Holcomb 2002; Sitnikova, Kuperberg et al. 2003). However, the distribution of the verbal and visual N400 differs, suggesting a functional similiarity but anatomical dissociation. Similarly, the P600 component could be dissociated from the N400 in cases of impossible event violations of the visual real-world (Sitnikova, Holcomb et al. 2008). The N400 has also been observed in the domain of music (Frey, Marie et al. 2009), where incongruous endings that do not indicate a tonal change can elicit N400. Steinbeis and Koelsch (2008) also described an N400-like component in the processing of tension-resolution patterns in music, namely the N500, which was found to be modulated by semantically unexpected sentences. The N500 can thus be interpreted as being indicative of the processing of semantic aspects of tension-resolution patterns. These findings not only provide further evidence for a possible overlap between language and music processing, but also for the close link between syntax, meaning and emotion in the domain of music. Certainly, these examples on the processing of meaning in the auditory and visual modalities illustrate that the brain seems to favour abstractions in order to generalize processes across domains, and further, that emotion and meaning cannot be strictly separated in music as it is the case in language.

3.4. Neural Correlates of Cross-Modal Emotional Transfer with Music

In the last decade, several studies applying affective and emotional priming paradigms have shed new light on the question of whether musical emotions are similarly or dissimilarly processed by the brain compared to emotions elicited by other domains [for general reviews, see (Calvert 2001; Carlesimo, Turriziani et al. 2004; Small 2004; Amedi, Kriegstein et al. 2005)]. Many of these studies used the paradigm of affective priming, which originated in social psychology and research on attitudes, stereotypes and preferences (Kunst-Wilson and Zajonc 1980). The attitude accessibility hypothesis states that the mere presentation of highly valenced objects or words increases the accessibility of the corresponding affective evaluation (Fazio, Sanbonmatsu et al. 1986). Typically, participants need to respond as quickly as possible to affectively positive or negative target words which are preceded by either positive or negative prime stimuli. Primes and targets can either be affectively congruent (e.g., love-holiday) or incongruent (e.g., love-war). Response latencies are mediated by the affective relationship between primes and targets: participants respond faster to a target when the prime is of the same valence as the target (Fazio, Sanbonmatsu et al. 1986; Bargh, Chaiken et al. 1992; Klauer 1998). Different types of tasks have been used in affective priming paradigms, such as to evaluate (Hermans, Baeyens et al. 1998) or pronounce (Bargh, Chaiken et al. 1996) the target, or to decide if the target is a word or non-word (Wentura 2000). Affective priming effects do not rely on conscious evaluations of the targets and are considered to be automatic (Fazio 2001), which has been shown by subliminal presentation of primes (Greenwald, Klinger et al. 1995; Draine and Greenwald 1998). Evidence for the generality of the affective priming effect has been provided by studies using different types of stimulus materials. For example, researchers mostly used visual stimuli such as words (Fazio, Sanbonmatsu et al. 1986; Bargh, Chaiken et al. 1992; Hermans, De Houwer et al. 1994), simple line drawings

(Giner-Sorolla, Garcia et al. 1999), complex real-life pictures (Hermans, De Houwer et al. 1994) and facial expressions (Murphy and Zajonc 1993). More recently, auditory verbal stimuli (Duckworth, Bargh et al. 2002) and odors (Hermans, Baeyens et al. 1998) were used as primes, indicating that affective priming effects occur across sensory modalities.

A number of recent studies on emotion have provided evidence for behavioural and neural cross-modal priming effects, investigating whether and how the emotional content of one sensory modality influences the interpretation of emotional information arising through other sensory modalities. In the case of music, this paradigm provides fruitful insights into the important question of whether emotions elicited by music are processed and interpreted in a similar or different way compared to emotion eliciting stimuli of other domains. A pioneering behavioural study was conducted by Bouhuys and colleagues (1995) who observed that listening to either depressing or elating music affected the perception of facial expressions. Participants who reported to be deeply negatively affected by the music rated ambiguous facial expressions (displaying less intense emotions) as more sad and clear facial expressions as less happy, which suggests a depression-related negative bias in the perception of emotional facial expressions. In another study, affective priming was observed using consonant and dissonant chords as priming stimuli and words as targets (Sollberger, Reber et al. 2003). In affectively congruent prime-target pairs, the targets were evaluated faster and with greater accuracy than in incongruent pairs. In the context of semantic priming, music was used as primes and shown to have an effect on the evaluation of simultaneously presented verbal stimuli (Poulin-Charronnat, Bigand et al. 2005). The harmonic expectedness of the final chord in a sequence modulated the performance in a lexical decision task. Moreover, induction of happiness and sadness by classical music affected word-naming and lexical decision tasks (Niedenthaland, Halberstadt et al. 1997). More recently, behavioral evidence for an affective priming effect was shown by film music in combination with film excerpts in which a single neutral character was shown and evaluated by the participants (Tan, Spackman et al. 2007). The film music excerpts, taken from the classical repertoire, did not vary along a single bipolar scale such as positive or negative, but were meant to induce happiness, sadness, fear or anger. The judgement of character’s emotions was found to be influenced by the specific emotion expressed by the music. Another study investigated the influence of visual and musical emotion induction on alcohol consumption (Stein, Goldman et al. 2000). Emotionally neutral and positive words or musical excerpts were presented before the alcohol consumption task. Participants consumed more alcohol after the presentation of positive words and music excerpts, indicating that auditory and visual information has an effect on other sensory channels such as taste. Interestingly, people suffering from alcoholism did not show a cross-modal facilitation effect in the processing of congruent emotional stimuli (Maurage, Campanella et al. 2007). Recently, Escoffier and Tillmann (2008) found that the speed of visual processing of syllables and geometric forms can be modulated by the tonal function of a task-irrelevant chord. Visual target identification was faster for contexts in which the musical context fulfilled listeners’ expectations, suggesting that attentional mechanisms can be influenced by musical structure. Music-induced emotion can also interfere with verbal recall performance. For example, prior listening to positive music was found to influence the encoding processes leading to an enhancement of false memory productions, whereas listening to negative excerpts reduced such effects, thereby increasing accuracy in memory performance (Storbeck and Clore 2005). Konecni and colleagues (2007) were interested in questions related to a more abstract transfer, and investigated whether the experience of music-induced chills could enhance the participants' degree of altruism, mood and prosocial self-concept after the presentation of stimuli in different modalities and aesthetic domains that also elicited chills. Chills elicited before listening to music were found to have no effect on the chills induced by the music. In addition, the experience of chills did not affect measures of altruism, mood and self-concept.

Before discussing the neural correlates of crossmodal affective priming, we first present a few studies which investigated the neural correlates of simultaneous processing of music and other sensory stimuli. Spreckelmeyer and colleagues (2006) conducted ERP recordings on audio-visual interactions while simultaneously presenting either congruent or incongruent pairs of sung notes and affective complex pictures taken from the International Affective Picture System (IAPS) (Lang, Bradley et al. 1995). Although the simultaneously presented sung notes were irrelevant for participants' picture affect ratings or vice versa, their affective contents showed interaction on both the behavioural and neural level (N1, P2 components) even when participants only paid attention to one of the modalities. Similarly, Sugimoto and colleagues (2007) made participants look at IAPS pictures of different valence while ERPs of unattended nonstartle probe tones were recorded. Participants were instructed to ignore the tones, which were either large/low deviant or standard tones. Negative pictures combined with high-deviant tones yielded a larger N1 component, whereas a smaller P2 was observed in the combination of positive pictures and standard tones. The amplitude of the mismatch negativity tended to decrease in the positive picture condition, probably due to the reduction of the P2 in the same condition. These results suggest that visually induced emotions have a sequential effect on the processing of auditory information: negative emotions influence the process at an earlier stage than positive emotions.

Baumgartner and colleagues (2006) investigated psychophysiological and neural responses to high-arousing IAPS pictures and excerpts of classical music inducing happiness, sadness or fear in three conditions: pictures alone, music alone or congruent picture-music pairs. Perceived emotions were most pronounced for the combined music-picture condition. Similarly, brain activation, as measured by the EEG power in the alpha band, was also observed to be largest for the combined condition. Interestingly, both perceived emotions and brain activations were larger for the picture only than for the music only condition. Using a similar set of stimuli in an fMRI study, the same group of authors found increased activation for combined conditions in most areas of the automatic ventral system of emotion perception, such as in the bilateral amygdala, ventral frontal cortex, left striatum, left insula, brainstem nuclei, and in the in the medial temporal lobe memory system (including the hippocampus and parahippocampus), which is generally regarded to be part of the cognitive dorsal system of emotion perception (Baumgartner, Lutz et al. 2006). More recently, the finding that strong emotional experiences can be elicited by combining visual and musical stimuli was applied in a transcranial magnetic stimulation study to examine whether emotional valence can modulate the hand-motor system and the associated corticospinal tract (Baumgartner, Willi et al. 2007). Irrespective of emotional valence, enhanced motor-evoked potentials were found in the combined condition compared to the unimodal presentation of the stimuli. Skin conductance responses were enhanced in both combined and music conditions but not in the picture condition, indicating that arousal is a necessary, but not sufficient, prerequisite for activation of the motor system of the brain. Baumgartner's approach clearly demonstrates the importance of combining multiple measures of emotional response in order to fully understand the underlying relationship between various psychological, psychophysiological and neurophysiological mechanisms in multisensory perception.

In a similar fashion, Eldar and colleagues (2007) combined visual and musical stimuli in an fMRI study. They combined neutral film clips and positive (happy), negative (scary) and neutral (simple and monotonic) musical clips in three conditions, music only, film only and combined. In a subsequent behavioural experiment, participants rated valence and arousal of the clips in order to ensure that the film clips provided concrete information and the musical clips emotional information. The combination of music and film was rated similarly to the music-only condition. The fMRI data indicated that the amygdala, the anterior hippocampus, and the lateral prefrontal cortex exhibited enhanced activation in the negative music-film condition compared to the unimodal presentation of the same stimuli. In addition, these regions were not activated in the music condition without films, suggesting that the emotional processing in the amygdala may be linked to its associated content, thus providing evidence for the cognitive approach in affective science (Lazarus 1991).

Chen and colleagues (2008) presented the first neuroscientific study of an affective priming paradigm with musical excerpts being used as affective primes. They were particularly interested in the negativity bias of emotional processing (Cacioppo and Gardner 1999) in the context of affective priming with Chinese music and complex pictures. The ERP data confirmed a clear negativity bias in either priming condition. Negative pictures elicited smaller P2 components than positive ones, and the difference of the amplitudes between positive and negative pictures was larger in the sad musical prime condition than in the happy musical prime condition. Moreover, negative pictures were characterized by more negative deflections during the 500-700ms interval across all prime types compared to positive pictures. Taken together, this study provides evidence that the brain is particularly sensitive to negative emotions and that this bias is enhanced in negative emotional states.

In a similar vein, Logeswaran and Bhattacharya (2009) further investigated whether musical emotions are similar or dissimilar compared to emotions induced by the visual domain by conducting two experiments and collecting behavioural and EEG data. Employing a priming paradigm, they used positive and negative musical excerpts in different styles with a duration of 15s as primes (Altenmüller, Schurmann et al. 2002), and visual stimuli showing happy, sad and neutral faces as targets. In the behavioural study, participants were asked to evaluate the valence of the faces and results confirmed a cross-modal priming effect: the happy faces were rated as more happy when presented after positive music, and the same was true for sad faces following negative music. Interestingly, the music-related priming effect was maximal for neutral targets. Their ERP results showed that for neutral face targets, positive music as compared to negative music elicited an enhanced N1 component, which is in line with the results by Pourtois and colleagues (2000), who found an enhanced N1 effect over auditory cortex in the case of the simultaneous presentation of emotionally congruent face-voice pairs. The N1 effect was spread over frontal regions, suggesting an involvement of brain regions responsible for top-down projections. ERP results also showed a priming related enhancement of the P2 component for happy and neutral target faces but not for sad targets, corroborating the finding by Spreckelmeyer and colleagues (2006). The functional role of the P2 component in such priming paradigms is still unclear, but current results suggest that the component is valence sensitive.

Future cross-modal priming studies may combine different types of emotional stimuli than the ones recently used in order to further investigate the effects of stimuli length, attention and explicit versus implicit measures of subjective experience on priming effects. Additionally, we propose that some of the current issues in research on induced musical emotions (see Sect. 2) should be incorporated in these experimental designs, leading to more refined research questions. Cross-modal emotional priming studies may also contribute to our understanding of the interaction between cognition and emotion in aesthetic experience, and crucially, help to answer the question whether musical emotions are same or different from emotions induced in other domains.

4. Conclusions

Our extensive discussion of the latest findings in research on emotions induced by music has aimed at addressing several current issues that primarily relate to comparisons between emotional processing and experience in different sensory domains. At the present stage, the unresolved questions clearly outnumbers the satisfying answers, as such providing an attractive young field for interdisciplinary research. We hope to have convincingly made the point that our understanding of musical emotions, and some of their special characteristics, can only be enhanced by critical cross-modal comparisons and by applying a wide range of different neuroscientific and behavioural techniques and paradigms in the future. We further suggest that cross-modal priming paradigms in particular may yield new answers to old questions referring to music. This is in line with Peretz (2001), who first argued in favour of studying musical emotions *indirectly* by the way they influence other tasks or behaviours *without explicit awareness*. In fact, this kind of indirect approach of studying music-induced emotions may also potentially increase our knowledge about emotions induced in other domains than music.

Acknowledgements

We would like to thank Marcel Zentner and Bruno Gingras for helpful comments. This research is partially supported by the JST.ERATO project and the Goldsmiths RKTC project (J.B.).

References

Abeles, H. F. & Chung, J. W. (1996). Response to music. *Handbook for music psychology*. D. A. Hodges. San Antonio, TX, Institute of Music Research, 285-342.

Altenmüller, E., Schürmann, K., et al. (2002). "Hits to the left, flops to the right: different emotions during listening to music are reflected in cortical lateralisation patterns." *Neuropsychologia*, *40(13)*, 2242-56.

Amedi, A., Kriegstein, K., et al. (2005). "Functional imaging of human crossmodal identification and object recognition." *Experimental Brain Research*, *166(3)*, 559-571.

Ayari, M. & McAdams, S. (2003). "Aural analysis of Arabic improvised instrumental music (taqsim)." *Music Perception*, *21(2)*, 159-216.

Balkwill, L. L., Thompson, W. F., et al. (2004). "Recognition of emotion in Japanese, Western, and Hindustani music by Japanese listeners." *Japanese Psychological Research, 46(4)*, 337-349.

Bar, M. & Aminoff, E. (2003). "Cortical analysis of visual context." *Neuron, 38*, 347-358.

Baraldi, F. B. (2009). "All the pain and joy of the world in a single melody: A Transylvanian case study on musical emotion." *Music Perception*, *26(3)*, 257-261.

Bargh, J. A., Chaiken, S., et al. (1992). "The generality of the automatic attitude activation effect." *Journal of Personality and Social Psychology, 62*, 893-912.

Bargh, J. A., Chaiken, S., et al. (1996). "The automatic evaluation effect: Unconditional automatic attitude activation with a pronunciation task." *Journal of Experimental Social Psychology, 32*, 104-128.

Baron-Cohen, S., Knickmeyer, R. C., et al. (2005). "Sex differences in the brain: Implications for explaining autism." *Science, 310*, 819-823.

Baumgartner, T., Esslen, M., et al. (2006). "From emotion perception to emotion experience: Emotions evoked by pictures and classical music." *International Journal of Psychophysiology, 60*, 34-43.

Baumgartner, T., Lutz, K., et al. (2006). "The emotional power of music: How music enhances the feeling of affective pictures." *Brain Research*, *1075(1)*, 151-64.

Baumgartner, T., Willi, M., et al. (2007). "Modulation of corticospinal activity by strong emotions evoked by pictures and classical music: A transcranial magnetic stimulation study." *Neuroreport*, *18(3)*, 261-5.

Beardsley, M. C. (1958). *Aesthetics: Problems in the philosophy of criticism*. New York, Harcourt.

Beardsley, M. C. (1966). *Aesthetics from classical Greece to the present*. New York, MacMillan.

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York, Appleton-Century-Crofts.

Besson, M., Magne, C., et al. (2002). "Emotional prosody: Sex differences in sensitivity to speech melody." *Trends in Cognitive Sciences*, *6(10)*, 405-407.

Bharucha, J. J. & Krumhansl, C. L. (1983). "The representation of harmonic structure in music: hierarchies of stability as a function of context." *Psychological Review*, *13*, 63-102.

Bharucha, J. J. & Stoeckig, K. (1986). "Reaction time and musical expectancy: Priming of chords." *Journal of Experimental Psychology: Human Perception & Performance*, *12*, 403-410.

Bhattacharya, J. & Petsche, H. (2001). "Enhanced phase synchrony in the electroencephalograph gamma band for musicians while listening to music." *Physical Review E Statistical, Nonlinear, & Soft Matter Physics, 64(1 Pt 1)*, 012902.

Bigand, E., Madurell, F., et al. (1999). "Effects of global structure and temporal organization on chord processing." *Journal of Experimental Psychology: Human Perception & Performance*, *25*, 184-197.

Bigand, E., Parncutt, R., et al. (1996). "Perception of musical tension in short tone sequences: The influence of harmonic function, sensory dissonance, horizontal motion and musical training." *Perception and Psychophysics*, *58(1)*, 125-141.

Bigand, E. & Poulin-Charronnat, B. (2006). "Are we "experienced listeners"? A review of the musical capacities that do not depend on formal musical training." *Cognition*, *100(1)*, 100-30.

Bigand, E., Vieillard, S., et al. (2005). "Multidimensional scaling of emotional responses to music: The effect of musical expertise and of the duration of the excerpts." *Cognition & Emotion*, *19(8)*, 1113-1139.

Blood, A. J. & Zatorre, R. J. (2001). "Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion." *Proceedings of the National Academy of Sciences of the United States of America*, *98(20)*, 11818-23.

Blood, A. J., Zatorre, R. J. et al. (1999). "Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions." *Nature Neuroscience*, *2(4)*, 382-387.

Bouhuys, A. L., Bloem, G. M., et al. (1995). "Induction of depressed and elated mood by music influences the perception of facial emotional expressions in healthy subjects." *Journal of Affective Disorders*, *33(4)*, 215-226.

Bourne, V. J. (2005). "Lateralised processing of positive facial emotion: sex differences in strength of hemispheric dominance." *Neuropsychologia*, *43(6)*, 953-956.

Bradley, M. M., Codispoti, M., et al. (2001). "Emotion and motivation II: Sex differences in picture processing." *Emotion*, *1(3)*, 300-319.

Brody, L. R. (1996). Gender, emotional expression and parent-child boundaries. *Emotion: Interdisciplinary perspectives*. R. D. Kavanaugh, B. Zimmerberg, & S. Fein (Eds.), Philadelphia, Lawrence Erlbaum Associates, 139-171.

Brody, L. R. & Hall, J. A. (2000). Gender, emotion, and expression. *Handbook of Emotions* M. Lewis, & J. M. Haviland (Eds.), New York, Guilford Press, 338-349.

Brown, S., Martinez, M. J., et al. (2004). "Passive music listening spontaneously engages limbic and paralimbic systems." *Neuroreport*, 2033-2037.

Brown, S., Martinez, M. J., et al. (2006). "Music and language side by side in the brain: A PET study on the generation of melodies and sentences." *European Journal of Neuroscience*, *23*, 2791-2803.

Cacioppo, J. T. & Gardner, W. L. (1999). "Emotion." *Annual Review of Psychology*, *50*, 191-214.

Cahill, L., Uncapher, M., et al. (2004). "Sex-related hemispheric lateralization of amygdala function in emotionally influenced memory: An fMRI investigation." *Learning & Memory*, *11(3)*, 261-266.

Calvert, G. A. (2001). "Crossmodal processing in the human brain: Insights from functional neuroimaging studies." *Cerebral Cortex*, *11*, 1110-1123.

Canli, T., Desmond, J. E., et al. (2002). "Sex differences in the neural basis of emotional memories." *Proceedings of the National Academy of Sciences of the United States of America*, *99(16)*, 10789-10794.

Canli, T., Desmond, J. E., et al. (1998). "Hemispheric asymmetry for emotional stimuli detected with fMRI." *Neuroreport*, *9(14)*, 3233-3239.

Carlesimo, G. A., Turriziani, P., et al. (2004). "Brain activity during intra- and cross-modal priming: New empirical data and review of the literature." *Neuropsychologia*, *42(1)*, 14-24.

Cela-Conde, C. J., Marty, G., et al. (2004). "Activation of the prefrontal cortex in the human visual aesthetic perception." *Proceedings of the National Academy of Sciences of the United Sates of America*, *101(16)*, 6321-6325.

Chen, J., Yuan, J., et al. (2008). "Music-induced mood modulates the strength of emotional negativity bias: An ERP study." *Neuroscience Letters*, *445(2)*, 135-139.

Collier, G. L. (2007). "Beyond valence and activity in the emotional connotations of music." *Psychology of Music*, *35*, 110-131.
Cross, I. & Morely, I. (2009). The evolution of music: Theories, definitions and the nature of the evidence. *Communicative musicality*. S. Malloch, & C. Trevarthen (Eds.), Oxford, Oxford University Press.
Cross, I. & Woodruff, G. E. (2009). Music as a communicative medium. *The prehistory of language*. R. Botha, & C. Knight (Eds.), Oxford, Oxford University Press.
Cummings, A., Ceponieni, R., et al. (2006). "Auditory semantic networks for words and natural sounds." *Brain Research*, *1115*, 92-107.
Cupchik, G. C., Vartanian, O., et al. (2009). "Viewing artworks: Contributions of cognitive control and perceptual facilitation to aesthetic experience." *Brain and Cognition*, *70(1)*, 84-91.
Davidson, R. J. (1993). The neuropsychology of emotion and affective style. *Handbook of emotion*. M. Lewis, & M. J. Haviland (Eds.), New York, *Guilford Press*, 143-154.
Davidson, R. J., Schwartz, G. E., et al. (1979). "Frontal versus parietal EEG asymmetry during positive and negative affect." *Psychophysiology*, *16*, 202-203.
DeNora, T. (2000). *Music in everyday life*. Cambridge, Cambridge University Press.
Di Dio, C., Macaluso, E., et al. (2007). "The golden beauty: Brain responses to classical and renaissance sculptures." *PLoS ONE*, *2(11)*, e1201.
Draine, S. C. & Greenwald, A. G. (1998). "Replicable unconscious semantic priming." *Journal of Experimental Psychology: General*, *127*, 286-303.
Duckworth, K. L., Bargh, J. A., et al. (2002). "The automatic evaluation of novel stimuli." *Psychological Science*, *13*, 513-519.
Earl of Shaftesbury, A. (1964/1711). Characteristics of men, manners, opinions, and times Indianapolis, Bobbs-Merrill.
Eerola, T., Himberg, T., et al. (2006). "Perceived complexity of western and African folk melodies by western and African listeners." *Psychology of Music*, *34(3)*, 337-371.
Egermann, H., Grewe, O., et al. (2009). "Social feedback influences musically induced emotions." *Annals of the New York Academy of Sciences*, *1169*, 346-350.
Ekman, P. (1999). Basic emotions. *Handbook of Cognition and Emotion*. T. Dalgleish, & M. Power (Eds.), Sussex, Wiley & Sons, Ltd.
Eldar, E., Ganor, O., et al. (2007). "Feeling the real world: Limbic responses to music depends on related content." *Cerebral Cortex*, *17(12)*, 2828-2840.
Epstein, R. & Kanwisher, N. (1998). "A cortical representation of the local visual environment." *Nature*, *392*, 598-601.
Escoffier, N. & Tillmann, B. (2008). "The tonal function of a task-irrelevant chord modulates speed of visual processing." *Cognition*, *107(3)*, 1070-1083.
Evans, P. & Schubert, E. (2008). "Relationships between expressed and felt emotions in music." *Musicae Scientiae*, *12(1)*, 75-99.
Fazio, R. H. (2001). "On the automatic activation of associated evaluations: An overview." *Cognition and Emotin*, *15*, (115-141).
Fazio, R. H., Sanbonmatsu, D. M., et al. (1986). "On the automatic activation of attitudes." *Journal of Personality and Social Psychology*, *50(2)*, 229-238.
Fedorenko, E., Patel, A. D., et al. (2009). "Structural integration in language and music: Evidence for a shared system." *Memory and Cognition*, *37*, 1-9.

Field, T., Martinez, A., et al. (1998). "Music shifts frontal EEG in depressed adolescents." *Adolescence*, *33*, 109-116.

Fischer, A. H. & Manstead, A. S. R. (2000). The relation between gender and emotions in different cultures. Gender and emotion: Social psychology perspectives A. H. Fisher. New York, *Cambridge University Press*, 71-79.

Flores-Gutiérrez, E. O., Diaz, J. L., et al. (2007). "Metabolic and electric brain patterns during pleasant and unpleasant emotions induced by music masterpieces." *International Journal of Psychophysiology*, *65(1)*, 69-84.

Flores-Gutiérrez, E. O., Díaz, J. L., et al. (2009). "Differential alpha coherence hemispheric patterns in men and women during pleasant and unpleasant musical emotions." *International Journal of Psychophysiology*, *71(1)*, 43-49.

Fox, N. A. (1991). "If it’s not left, it’s right: Electroencephalograph asymmetry and the development of emotion." *American Psychologist*, *46*, 863-872.

Frey, A., Marie, C., et al. (2009). "Temporal semiotic units as minimal meaningful units in music? An electrophysiological approach." *Music Perception*, *26(3)*, 247-256.

Frijda, N. H. (1988). "The laws of emotion." *American Psychologist*, *43(5)*, 349-358.

Frijda, N. H. & Sundararajan, L. (2007). "Emotion refinement: A theory inspired by Chinese poetics." *Perspectives on Psychological Science*, *2(3)*, 227-241.

Frith, S. (2004). What is bad music? *Bad music: The music we love to hate*. C. J. Washburne, & M. Derno. New York, Routledge.

Fritz, T., Jentschke, S., et al. (2009). "Universal recognition of three basic emotions in music." *Current Biology*, *19(7)*, 573-576.

Gabrielsson, A. (2002). "Emotion perceived and emotion felt." *Musicae Scientiae*, 2001-2002(Special issue): 123-147.

Gabrielsson, A. & Juslin, P. N. (1996). "Emotional expression in music performance: Between the performer's intention and the listener's experience." *Psychology of Music*, *24(1)*, 68-91.

Gerra, G., Zaimovic, A., et al. (1998). "Neuroendocrine responses of healthy volunteers to 'techno-music': Relationships with personality traits and emotional state." *International Journal of Psychophysiology*, *28(1)*, 99-111.

Giner-Sorolla, R., Garcia, M. T., et al. (1999). "The automatic evaluation of pictures." *Social Cognition*, *17*, 76-96.

Gosselin, N., Peretz, I., et al. (2007). "Amygdala damage impairs emotion recognition from music." *Neuropsychologia*, *45(2)*, 236-44.

Gosselin, N., Peretz, I., et al. (2005). "Impaired recognition of scary music following unilateral temporal lobe excision." *Brain*, *128(Pt 3)*, 628-40.

Gottselig, J. M. (2000). Human neuroanatomical systems for perceiving emotion in music. Iowa City, University of Iowa. PhD.

Greenwald, A. G., Klinger, M. R., et al. (1995). "Activation by marginally perceptible (“subliminal”) stimuli: Dissociation of unconscious from conscious cognition." *Journal of Experimental Psychology: General*, *124*, 22-42.

Gross, J. J. (2007). *Handbook of emotion regulation*. New York, Guilford Press.

Guhn, M., Hamm, A., et al. (2007). "Physiological and musico-acoustic correlates of the chill response." *Music Perception*, *24(5)*, 473-483.

Hamann, S. & Canli, T. (2004). "Individual differences in emotion processing." *Current Opinion in Neurobiology*, *14(2)*, 233-238.

Han, S. & Northoff, G. (2008). "Culture-sensitive neural substrates of human cognition: A transcultural neuroimaging approach." *Nature Review Neuroscience*, *9(8)*, 646-654.

Hannon, E. E. & Trainor, L. J. (2007). "Music acquisition: Effects of enculturation and formal training on development." *Trends in Cognitive Sciences*, *11(11)*, 466-472.

Hargreaves, D. J. (1984). "The effects of repetition on liking for music." *Journal of Research in Music Education*, *32(1)*, 35-47.

Hargreaves, D. J. & North, A. C. (1999). "The functions of music in everyday life: Redefining the social in music psychology." *Psychology of Music*, *27(1)*, 71-83.

Hays, T. & Minichiello, V. (2005). "The meaning of music in the lives of older people: A qualitative study." *Psychology of Music*, *33(4)*, 437-451.

Heilman, K. M. (1997). "The neurobiology of emotional experience." *Journal of Neuropsychiatry and Clinical Neuroscience*, *9*, 439-448.

Heller, W. (1993). "Neuropsychological mechanisms of individual differences in emotion, personality, and arousal." *Neuropsychology*, *7*, 476-489.

Hermans, D., Baeyens, F., et al. (1998). "Odours as affective processing context for word evaluation: A case of cross-modal affective priming." *Cognition and Emotion*, *12*, 601-613.

Hermans, D., De Houwer, J., et al. (1994). "The affective priming effect: Automatic activation of evaluative information in memory." *Cognition and Emotion*, *8*, 515-533.

Herrington, J. D., Mohanty, A., et al. (2005). "Emotion-modulated performance and activity in left dorsoateral prefrontal cortex." *Emotion*, *5(2)*, 200-207.

Höfel, L. & Jacobsen, T. (2007). "Electrophysiological indices of processing aesthetics: Spontaneous or intentional processes?" *International Journal of Psychophysiology*, *65(1)*, 20-31.

Holcomb, P. & McPherson, W. B. (1994). "Event-related brain potentials reflect semantic priming in an object decision task." *Brain & Cognition*, *24*, 259-276.

Hutcheson, F. (1725). *An inquiry into the original of our ideas of beauty and virtue*. London, D. Midwinter and Others.

International Federation of Phonographic Industry (IFPI) (2006) Recorded music – Driver of a US$100 billion economic sector. Press Release, 22nd June.

Izard, C. E. (2007). "Basic emotions, natural kinds, emotion schemas, and a new paradigm." *Perspectives on Psychological Science*, *2*, 260-280.

Jackendoff, R. (2002). Foundation of language: Brain, meaning, grammar, evolution. Oxford, Oxford University Press.

Jackendoff, R. (2009). "Parallels and nonparallels between music and language." *Music Perception*, *26(3)*, 195-203.

Jacobsen, T., Schubotz, R. I., et al. (2006). "Brain correlates of aesthetic judgment of beauty." *NeuroImage*, *29(1)*, 276-285.

Jeffries, K., Fritz, J., et al. (2003). "Words in melody: An H215O PET study of brain activation during singing and speaking." *Neuroreport*, *14*, 749-754.

Jentschke, S., Koelsch, S., et al. (2008). "Children with specific language impairment also show impairment of music-syntactic processing." *Journal of Cognitive Neuroscience*, *20(11)*, 1-12.

Johnsen, E. L., Tranel, D., et al. (2009). "A neuroanatomical dissociation for emotion induced by music." *International Journal of Psychophysiology*, *72*, 24-33.

Juslin, P. N. (2000). "Cue utilization in communication of emotion in music performance: Relating performance to perception." *Journal of Experimental Psychology: Human Perception & Performance*, *26(6)*, 1797-813.

Juslin, P. N. & 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. & Laukka, P. (2004). "Expression, perception, and induction of musical emotions: A review and a questionnaire study of everyday listening." *Journal of New Music Research*, *33(3)*, 217 - 238.

Juslin, P. N., Liljeström, S., et al. (2008). "An experience sampling study of emotional reactions to music: Listener, music, and situation." *Emotion*, *8(5)*, 668-683.

Juslin, P. N. & Sloboda, J. A. Eds. (2001). Music and emotion: Theory and research. Oxford, Oxford University Press.

Juslin, P. N. & Sloboda, J. A. (2001). Psychological perspectives on music and emotion. *Music and emotion*. P. N. Juslin, & J. A. Sloboda (Eds.), Oxford, Oxford University Press, 71-104.

Juslin, P. N. & Sloboda, J. A. Eds. (2009). *Handbook of music and emotion: Theory, research, applications*. New York, Oxford University Press.

Juslin, P. N. & Västfjäll, D. (2008). "Emotional responses to music: The need to consider underlying mechanisms." *Behavioral and Brain Sciences*, *31(5)*, 559-621.

Kallinen, K. & Ravaja, N. (2006). "Emotion perceived and emotion felt: Same and different." *Musicae Scientiae*, *10(2)*, 191-213.

Kant, I. (1914/1790). *Critique of judgment*. London, MacMillan.

Kawabata, H. & Zeki, S. (2004). "Neural Correlates of Beauty." *Journal of Neurophysiology*, *91(4)*, 1699-1705.

Kemal Arikan, M., Devrim, M., et al. (1999). "Music effects on event-related potentials of humans on the basis of cultural environment." *Neuroscience Letters*, *268(1)*, 21-24.

Khalfa, S., Peretz, I., et al. (2002). "Event-related skin conductance responses to musical emotions in humans." *Neuroscience Letters*, *328(2)*, 145-9.

Khalfa, S., Roy, M., et al. (2008). "Role of tempo entrainment in psychophysiological differentiation of happy and sad music?" *International Journal of Psychophysiology*, *68(1)*, 17-26.

Khalfa, S., Schon, D., et al. (2005). "Brain regions involved in the recognition of happiness and sadness in music." *Neuroreport*, *16(18)*, 1981-4.

Kirk, U., Skov, M., et al. (2009). "Brain correlates of aesthetic expertise: A parametric fMRI study." *Brain and Cognition*, *69(2)*, 306-315.

Kirk, U., Skov, M., et al. (2009). "Modulation of aesthetic value by semantic context: An fMRI study." *NeuroImage*, *44(3)*, 1125-1132.

Kivy, P. (1989). *Sound sentiment: An essay on the musical emotions including the complete text of The Corded Shell*. Philadelphia, Temple University Press.

Kivy, P. (1990). *Music alone: Philosophical reflection on the purely musical experience*. Ithaca, NY, Cornell University Press.

Klauer, K. C. (1998). Affective priming. *European Review of Social Psychology*. W. Stroebe & M. Hewstone (Eds.), New York, John Wiley & Sons Inc.

Koelsch, S. (2005). "Investigating emotion with music: Neuroscientific approaches." *Annals of the New York Academy of Sciences*, *1060*, 412-418.

Koelsch, S. & Friederici, A. D. (2003). "Towards the neural basis of processing structure in music: Comparative results of different neurophysiological investigation methods (EEG, MEG, fMRI)." *Annals of the New York Academy of Sciences*, *999*, 15-27.

Koelsch, S., Fritz, T., et al. (2006). "Investigating emotion with music: An fMRI study." *Human Brain Mapping*, *27(3)*, 239-250.

Koelsch, S., Fritz, T., et al. (2008). "Amygdala activity can be modulated by unexpected chord functions during music listening." *Neuroreport*, *19(18)*, 1815-9.

Koelsch, S., Grossmann, T., et al. (2003). "Children Processing Music: Electric Brain Responses Reveal Musical Competence and Gender Differences." *Journal of Cognitive Neuroscience*, *15(5)*, 683-693.

Koelsch, S., Gunter, T., et al. (2000). "Brain indices of music processing: "nonmusicians" are musical." *J Cogn Neurosci*, *12(3)*, 520-41.

Koelsch, S., Gunter, T. C., et al. (2002). "Bach speaks: A cortical “language network” serves the processing of music." *NeuroImage*, *17*, 1565-1577.

Koelsch, S., Gunter, T. C., et al. (2005). "Interaction between syntax processing in language and music: An ERP study." *Journal of Cognitive Neuroscience*, *17(10)*, 1565-1577.

Koelsch, S., Maess, B., et al. (2003). "Electric brain responses reveal gender differences in music processing." *Neuroreport*, *14(5)*, 709-13.

Konecni, V. J. (2008). "Does music induce emotion? A theoretical and methodological analysis." *Psychology of Aesthetics, Creativity, and the Arts*, *2(2)*, 115-129.

Konecni, V. J., Brown, A., et al. (2008). "Comparative effects of music and recalled life-events on emotional state." *Psychology of Music*, *36(3)*, 289-308.

Konecni, V. J., Wanic, R. A., et al. (2007). "Emotional and aesthetic antecedents and consequences of music-induced thrills." *American Journal of Psychology*, *120(4)*, 619-643.

Kotz, S. A., Meyer, M., et al. (2003). "On the lateralization of emotion prosody: An event-related functional MR investigation." *Brain and Language*, *86(3)*, 366-376.

Kreutz, G., Bongard, S., et al. (2002). "Kardiovaskuläre Wirkungen beim Musikhören. Zur Bedeutung von musikalischer Expertise und Emotion " *Musicae Scientiae*, *6*, 257-278.

Kreutz, G. & Lotze, M. (2007). Neuroscience of music and emotion. *The neuroscience of music education*. W. Gruhn, & F. Raucher (Eds.), New York, Nova Science Publishers, 145-169.

Kreutz, G., Ott, U., et al. (2008). "Using music to induce emotions: Influences of musical preference and absorption." *Psychology of Music*, *36(1)*, 101-126.

Kring, A. M. & Gordon, A. H. (1998). "Sex differences in emotion: expression, experience, and physiology." *Journal of Personality and Social Psychology*, *74(3)*, 686-703.

Krumhansl, C. L. (1996). "A perceptual analysis of Mozart’s Piano Sonata K. 282, Segmentation, tension and musical ideas.." *Music Perception*, *13*, 401-432.

Krumhansl, C. L. (2002). "Music: A link between cognition and emotion." *Current Directions in Psychological Science*, *11(2)*, 45-50.

Krumhansl, C. L. & Agres, K. R. (2008). "Musical expectancy: The influence of musical structure on emotional response." *Behavioral and Brain Sciences*, *31(5)*, 584-585.

Krumhansl, C. L. & Kessler, E. J. (1982). "Tracing the dynamic changes in peceived tonal organization in a spatial representation of musical keys." *Psychological Review*, *89*, 334-368.

Krumhansl, C. L., Toivanen, P., et al. (2000). "Cross-cultural music cognition: cognitive methodology applied to North Sami yoiks." *Cognition*, *76(1)*, 13-58.

Kunst-Wilson, W. R. & Zajonc, R. B. (1980). "Affective discrimination of stimuli that cannot be recognized." *Science*, *207*, *4430*, 557-558.

Kuperberg, G. R. (2007). "Neural mechanisms of language processing: Challenges to syntax." *Brain Research*, *1146*, 23-49.

Kutas, M. & Hillyard, S. A. (1980). "Reading senseless sentences: Brain potential reflect semantic incongruity." *Science*, *207*, 203-205.

Lang, P. L., Bradley, M. M., et al. (1995). International Affective Picture System (IAPS): Technical manual and affective ratings. Gainesville, FL., *The Center for Research in Psychophysiology*, University of Florida.

Lanteaume, L., Khalfa, S., et al. (2007). "Emotion induction after direct intracerebral stimulations of human amygdala." *Cerebral Cortex*, *17*, 1307-1313.

Larsen, J. T., Norris, C. J., et al. (2003). "Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii." *Psychophysiology*, *40*, 776-785.

Laukka, P. (2007). "Uses of music and psychological well-being among the elderly." *Journal of Happiness Studies*, *8*, 215-241.

Lazarus, R. S. (1991). "Cognition and motivation in emotion." *American Journal of Psychology*, *46*, 352-367.

Logeswaran, N. & Bhattacharya, J. (2009). "Crossmodal transfer of emotion by music." *Neuroscience Letters*, *455(2)*, 129-33.

Longhurst, B. (2007). *Pop music and society*. Cambridge, Polity Press.

Maess, B., Koelsch, S., et al. (2001). "Musical syntax is processed in Broca’s area: An MEG study." *Nature Neuroscience*, *4(5)*, 540-545.

Marin, M. M., Parncutt, R., et al. (2007). Emotion and unfamiliar music: Electrophysiological and psychological responses to Persian and Western music by Persian and Western listeners. Meeting of the Society for Music Perception and Cognition (SMPC). *Montreal*, Canada.

Maurage, P., Campanella, S., et al. (2007). "The crossmodal facilitation effect is disrupted in alcoholism. A study with emotional stimuli." *Alcohol*, *42(6)*, 552-559.

Mauss, I. B. & Robinson, M. D. (2009). "Measures of emotion: A review." *Cognition and Emotion*, *23(2)*, 209-237.

McAdams, S., Vines, B. W., et al. (2004). "Influences of large-scale form on continuous ratings in response to a contemporary piece in a live concert setting." *Music Perception*, *22(2)*, 297-350.

McMullen, (1996). The musical experience and affective/aesthetic responses: A theoretical framework for empirical research. *Handbook for music psychology*. D. A. Hodges (Editor), San Antonio, TX, *Institute for Music Research*, 387-400.

Menon, V. & Levitin, D. J. (2005). "The rewards with music listening: Response and physiological connectivity of the mesolimbic system." *NeuroImage*, *28*, 175-184.

Merriam, A. P. (1964). *The anthropology of music*. Evanston, Northwestern University Press.

Meyer, L. B. (1956). *Emotion and meaning in music*. Chicago, Chicago University Press.

Meyer, M., Steinhauer, K., et al. (2004). "Brain activity varies with modulation of dynamic pitch variances in sentence melody." *Brain and Language*, *89*, 277-289.

Mithen, S. J. (2005). The singing Neanderthals: The origins of music, language, mind and body. London, Weidenfeld & Nicholson.

Mitterschiffthaler, M. T., Fu, C. H., et al. (2007). "A functional MRI study of happy and sad affective states induced by classical music." *Human Brain Mapping*, *28(11)*, 1150-62.

Molnar-Szakacs, I. & Overy, K. (2006). "Music and mirror neurons: From motion to 'e'motion." *Soc Cogn Affect Neurosci*, *1(3)*, 235-241.

More, T., Logan, G. M., et al. (2002). *Utopia*. Cambridge, U.K.; New York, Cambridge University Press.

Morris, J., Scott, S., et al. (1999). "Saying it with feeling: Neural responses to emotional vocalizations." *Neuropsychologia*, *37*, 1155-1163.

Morrison, S. J., Demorest, S. M., et al. (2003). "FMRI investigation of cross-cultural music comprehension." *NeuroImage*, *20(1)*, 378-384.

Moss, S. A., Garivaldis, F. J., et al. (2007). "The perceived similarity of other individuals: The contaminating effects of familiarity and neuroticism." *Personality and Individual Differences*, *43(2)*, 401-412.

Murphy, S. T. & Zajonc, R. B. (1993). "Affect, cognition, and awareness: Affective priming with optimal and suboptimal stimulus exposures." *Journal of Personality and Social Psychology*, *64*, 723-739.

Nan, Y., Knösche, T. R., et al. (2006). "The perception of musical phrase structure: A cross-cultural ERP study." *Brain Research*, *1094(1)*, 179-191.

Nater, U. M., Abbruzzese, E., et al. (2006). "Sex differences in emotional and psychophysiological responses to musical stimuli." *International Journal of Psychophysiology*, *62(2)*, 300-8.

Nettle, D. (2007). "Empathizing and systemizing: What are they, and what do they contribute to our understanding of psychological sex differences?" *British Journal of Psychology*, *98*, 237-255.

Niedenthaland, P. M., Halberstadt, J. B., et al. (1997). "Being happy and "seeing" happy: Emotional state mediates visual word recognition." *Cognition and Emotion*, *11(4)*, 403-432.

North, A. C., Hargreaves, D. J., et al. (2004). "Uses of music in everyday life." *Music Perception*, *22(1)*, 41-77.

Orr, M. G. & Ohlsson, S. (2005). "Relationship between complexity and liking as a function of expertise." *Music Perception*, *22(4)*, 583-611.

Pallesen, K. J., Brattico, E., et al. (2005). "Emotion processing of major, minor, and dissonant chords: a functional magnetic resonance imaging study." *Annals of the New York Academy of Sciences*, *1060*, 450-3.

Parncutt, R. & Marin, M. M. (2006). Emotions and associations evoked by unfamiliar music. H. Gottesdiener & J.-C. Vilatte (Eds.), Culture and Communication: Proceedings of the International Association of Empirical Aesthetics. Avignon: IAEA.725-9.

Patel, A. D. (2003). "Language, music, syntax, and the brain." *Nature Neuroscience*, *6*, 674-681.

Patel, A. D. (2008). *Music, language, and the brain*. Oxford, Oxford University Press.

Patel, A. D. (2009). Language, music, and the brain: A resource-sharing framework. *Language and Music as Cognitive Systems*. P. Rebuschat, M., Rohrmeier, J. Hawkins & I. Cross (Eds.), Oxford, Oxford University Press.

Patel, A. D., Gibson, E., et al. (1998). "Processing syntactic relations in language and music: An event-related potential study." *Journal of Cognitive Neuroscience*, *10*, 717-733.

Peretz, I. (1996). "Auditory atonalia for melodies." *Cognitive Neuropsychology, 10*, 21-56.

Peretz, I. (2001). Listen to the brain: A biological perspective on musical emotions. *Music and emotion: Theory and research*. P. N. Juslin, & J. A. Sloboda (Eds.), Oxford, Oxford University Press, 105-134.

Peretz, I. (2009). Music, language and modularity in action. *Language and music as cognitive systems*. P., Rebuschat, M., Rohrmeier, J., Hawkins, & I. Cross. Oxford, Oxford University Press.

Peretz, I. (in press). Towards a neurobiology of musical emotions. *Handbook of music and emotion: Theory, research and applications.* P. N. Juslin, & J. A. Sloboda (Eds.), Oxford, Oxford University Press.

Peretz, I., Gaudreau, D., et al. (1998). "Exposure effects on music preference and recognition." *Memory and Cognition*, *26(5)*, 884-902.

Phelps, E. A. (2004). "Human emotion and memory: Interactions of the amygdala and hippocampal complex." *Current Opinion in Neurobiology*, *14*, 198-202.

Pietrzak, R. H., Laird, J. D., et al. (2002). "Sex differences in human jealousy: A coordinated study of forced-choice, continuous rating-scale, and physiological responses on the same subjects." *Evolution and Human Behavior*, *23(2)*, 83-94.

Pignatiello, M. F., Camp, C. J. et al. (1986). "Musical mood induction: An alternative to the Velten technique." *Journal of Abnormal Psychology*, *95(3)*, 295-297.

Posner, J., Russell, J. A., et al. (2005). "The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology." *Development and Psychopathology*, *17(03)*, 715-734.

Poulin-Charronnat, B., Bigand, E., et al. (2005). "Musical structure modulates semantic priming in vocal music." *Cognition*, *94*, B67-B78.

Pourtois, G., de Gelder, B., et al. (2000). "The time-course of intermodal binding between seeing and hearing affective information." *Neuroreport*, *11*, 1329-1333.

Rawlings, D. & Leow, S. H. (2008). "Investigating the role of psychoticism and sensation seeking in predicting emotional reactions to music." *Psychology of Music*, *36(3)*, 269-287.

Rentfrow, P. J. & Gosling, S. D. (2003). "The do re mi's of everyday life: The structure and personality correlates of music preferences." *Journal of Personality and Social Psychology*, *84(6)*, 1236-1256.

Richardson, M. P., Strange, B. A., et al. (2004). "Encoding of emotional memories depends on amygdala and hippocampus and their interactions." *Nature Neuroscience*, *7*, 278-285.

Rickard, N. S. (2004). "Intense emotional responses to music: a test of the physiological arousal hypothesis." *Psychology of Music*, *32(4)*, 371-388.

Ritossa, D. A. & Rickard, N. S. (2004). "The relative utility of 'pleasantness' and 'liking' dimensions in predicting the emotions expressed by music." *Psychology of Music, 32(1)*, 5-22.

Rosenbaum, R. S., McKinnon, M. C., et al. (2004). "Visual imagery deficits, impaired strategic retrieval, or memory loss: Disentangling the nature of an amnesic person's autobiographical memory deficit." *Neuropsychologia*, *42*, 1619-1635.

Roy, M., Mailhot, J. P., et al. (2009). "Modulation of the startle reflex by pleasant and unpleasant music." *International Journal of Psychophysiology*, *71(1)*, 37-42.

Royet, J. P., Plailly, J., et al. (2003). "fMRI of emotional responses to odors: Influence of hedonic valence and judgment, handedness, and gender." *NeuroImage*, *20(2)*, 713-728.

Royet, J. P., Zald, D. H., et al. (2000). "Emotional responses to pleasant and unpleasant olfactory, visual, and auditory stimuli: A positron emission tomography study." *Journal of Neuroscience*, *20*, 7752-7759.

Russell, J. A. (1980). "A circumplex model of affect." *Journal of Personality and Social Psychology*, *39(6)*, 1161-1178.

Saarikallio, S. & Erkkilä, J. (2007). "The roles of music in adolescents' mood regulation." *Psychology of Music*, *35*, 88-109.

Sachs-Ericsson, N. & Ciarlo, J. A. (2000). "Gender, social roles and mental health: An epidemiological perspective." *Sex Roles, 43(9-10),* 605-628.

Sammler, D., Grigutsch, M., et al. (2007). "Music and emotion: Electrophysiological correlates of the processing of pleasant and unpleasant music." *Psychophysiology*, *44(2)*, 293-304.

Sander, K. & Scheich, H. (2001). "Auditory perception of laughing and crying activates human amygdala regardless of attentional state." *Cognitive Brain Research*, *12*, 181-198.

Saunders, T. E., Ed. (1992). *The Politics*. London, Penguin Books.

Schellenberg, E. G., Peretz, I., et al. (2008). "Linking for happy- and sad-sounding music: Effects of exposure." *Cognition and Emotion*, *22*, 218-237.

Scherer, K. R. (2004). "Which emotions can be induced by music? What are the underlying mechanisms? And how can we measure them?" *Journal of New Music Research*, *33(3)*, 239-251.

Scherer, K. R. & Zentner, M. (2001). "Emotional effects of music: Production rules." P. N. Julsin, & J. A. Sloboda (Eds.), *Music and emotion: Theory and research*. Oxford, Oxford University Press, 361-392.

Scherer, K. R. & Zentner, M. (2008). "Music evoked emotions are different – More often aesthetic than utilitarian." *Behavioral and Brain Sciences*, *31(5)*, 595-596.

Schienle, A., Schäfer, A., et al. (2005). "Gender differences in the processing of disgust- and fear-inducing pictures: an fMRI study." *Neuroreport*, *16(3)*, 277-280.

Schimmack, U. & Grob, A. (2000). "Dimensional models of core affect. A quantitative comparison by means of structural equation modeling." *European Journal of Personality*, *14*, 325-345.

Schmidt, L. A. & Trainor, L. (2001). "Frontal brain electrical activity (EEG) distinguishes valence and intensity of musical emotions." *Cognition and Emotion*, *15(4)*, 487-500.

Scholten, M. R. M., Aleman, A., et al. (2005). "Schizophrenia and processing of facial emotions: Sex matters." *Schizophrenia Research*, *78(1)*, 61-67.

Schopenhauer, A. (1969/1818). *The world as will and representation*. New York, Dover.

Schubert, E. (1996). "Enjoyment of negative emotions in music: An associative network explanation." *Psychology of Music*, *24*, 18-28.

Schubert, E. (2004). "Modeling Perceived Emotion With Continuous Musical Features." *Music Perception*, *21(4)*, 561-585.

Schubert, E. (2007). "The influence of emotion, locus of emotion and familiarity upon preference in music." *Psychology of Music*, *35(3)*, 499-515.

Schultz, W. (2000). "Multiple reward signals in the brain." *Nature Review Neuroscience*, *1*, 199-207.

Schwartz, K. D. & Fouts, G. T. (2003). "Music preferences, personality style, and developmental issues of adolescents." *Journal of Youth and Adolescence*, *32(3)*, 205-213.

Shaver, P., Schwartz, J., et al. (1987). Emotion knowledge: Further exploration of a prototype approach. *Journal of Personaity andl Social Psychology, 52(6)*, 1061-1086.

Sitnikova, T., Holcomb, P., et al. (2008). "Two neurocognitive mechanisms of semantic integration during the comprehension of visual real-world events." *Journal of Cognitive Neuroscience*, *20(11)*, 2037-2057.

Sitnikova, T., Kuperberg, G. R., et al. (2003). "Semantic integration in videos of real-world events: An electrophysiological investigation." *International Journal of Psychophysiology*, *40*, 160-164.

Skov, M. & Vartanian, O. (2009). *Neuroaesthetics*. AmityVille, New York, Baywood Publishing Company Inc.

Slevc, L. R., Rosenberg, J. C., et al. (2009). "Making psycholinguistics musical: Self-paced reading time evidence for shared processing of linguistic and musical syntax." *Psychon Bull Rev*., *16(2)*, 374-81.

Sloboda, J. A. (2000). "Individual differences in music performance." *Trends in Cognitive Sciences*, *4(10)*, 397-403.

Sloboda, J. A. & 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.

Small, D. M. (2004). "Crossmodal integration - insights from the chemical senses." *Trends in Neurosciences*, *27(3)*, 120-123.

Sollberger, B., Reber, R., et al. (2003). "Musical chords as affective priming context in a word-evaluation task." *Music Perception*, *20(3)*, 263-282.

Spreckelmeyer, K. N., Kutas, M., et al. (2006). "Combined perception of emotion in pictures and musical sounds." *Brain Research*, *1070(1)*, 160-70.

Stein, K. D., Goldman, M. S., et al. (2000). "The influence of alcohol expectancy priming and mood manipulation on subsequent alcohol consumption." *Journal of Abnormal Psychology*, *109*, 106-115.

Steinbeis, N. & Koelsch, S. (2008). "Shared neural resources between music and language indicate semantic processing of musical tension-resolution patterns." *Cerebral Cortex*, *18(5)*, 1169-78.

Steinbeis, N., Koelsch, S., et al. (2006). "The role of harmonic expectancy violations in musical emotions: Evidence from subjective, physiological, and neural responses." *Journal of Cognitive Neuroscience*, *18(8)*, 1380-93.

Storbeck, J. & Clore, G. L. (2005). "With sadness comes accuracy; with happiness, false memory: mood and the false memory effect." *Psychological Science*, *16(10)*, 785-91.

Sugimoto, S., Nittono, H., et al. (2007). "Visual emotional context modulates brain potentials elicited by unattended tones." *International Journal of Psychophysiology*, *66*, 1-9.

Szpunar, K. K., Schellenberg, E. G., et al. (2004). "Liking and memory for musical stimuli as a function of exposure." Journal of Experimental Psychology: *Learning, Memory, and Cognition*, *30(2)*, 370-381.

Tan, S. L., Spackman, M. P., et al. (2007). "Viewer's interpretations of film characters' emotions: Effects of presenting film music before or after a character is shown." *Music Perception*, *25(2)*, 135-152.

Tan, S. L., Spackman, M. P., et al. (2006). "The effects of repeated exposure on liking and judgments of musical unity of intact and patchwork compositions." *Music Perception, 23(5)*, 407-421.

Tettamanti, M., Buccino, G., et al. (2005). "Listening to action-related sentences activates fronto-parietal motor circuits." *Journal of Cognitive Neuroscience*, *17*, 273-281.

Tsang, C. D., Trainor, L., et al. (2005). "Frontal EEG responses as a function of affective musical features." *Annals of the New York Academy of Sciences*, *1060*.

Vartanian, O. & Goel, V. (2004). "Neuroanatomical correlates of aesthetic preference for paintings." *Neuroreport*, *15(5)*.

Vogt, B. A. (2005). "Pain and emotion interaction in subregions of the cingulate gyrus." *Nature Review Neuroscience*, *6*, 533-544.

Wager, T. D., Phan, K. L., et al. (2003). "Valence, gender, and lateralization of functional brain anatomy in emotion: a meta-analysis of findings from neuroimaging." *NeuroImage*, *19(3)*, 513-531.

Wallenstein, G. (2008). *The pleasure instinct: Why we crave adventure, chocolate, pheromones and music*. Hoboken, John Wiley & Sons.

Wallin, N. L., Merker, B., et al., Eds. (1999). *The origins of music*. Cambridge, MA, MIT Press.

Wentura, D. (2000). "Dissociative affective and associative priming effects in the lexical decision task: Yes versus no responses to word targets reveal evaluative judgment tendencies." *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 456-469.

West, W. C. & Holcomb, P. J. (2002). "Event-related potentials during discourse-level semantic integration of complex pictures." *Brain Research: Cognitive Brain Research*, *13*, 363-375.

Wicke, P. (1990). *Rock music: Culture, aesthetics and sociology*. Cambridge, Cambridge University Press.

Wildgruber, D., Pihan, H., et al. (2002). "Dynamic brain activation during processing of emotional intonation: Influence of acoustic parameters, emotional valence, and sex." *NeuroImage*, *15(4)*, 856-869.

Witvliet, C. V. & Vrana, S. R. (2007). "Play it again Sam: Repeated exposure to emotionally evocative music polarises liking and smiling responses, and influences other affective reports, facial EMG, and heart rate." *Cognition & Emotion*, *21(1)*, 3-25.

Wong, P. C., Perrachione, T. K., et al. (2009). "Effects of asymmetric cultural experiences on the auditory pathway: evidence from music." *Annals of the New York Academy of Sciences*, 1169, 157-63.

Zajonc, R. B. (1968). "Attitudinal effects of mere exposure." *Journal of Personality and Social Psychology*, *9*, 1-27.

Zajonc, R. B. (2001). "Mere Exposure: A Gateway to the subliminal." *Current Directions in Psychological Science*, *10(6)*, 224-228.

Zentner, M., Grandjean, D., et al. (2008). "Emotions evoked by the sound of music: Characterization, classification, and measurement." *Emotion*, *8(4)*, 494-521.