CHAPTER 20

PROCESSING EMOTIONS INDUCED BY MUSIC

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Abstract

Can music induce emotions directly and, if so, are these emotions experienced similarly to emotions arising in other contexts? We explore these questions from the perspective of neuroscience. Emotional processing has a deep evolutionary history because it is essential for self-regulation and social approach vs withdrawal. In humans, emotional processing involves autonomic, subcortical, and cortical structures. Despite the fact that music does not appear to have an obvious survival value for modern adults, research indicates that listening to music does activate autonomic, subcortical, and cortical systems in a manner similar to other emotional stimuli. We propose that music may be so intimately connected with emotional systems because caregivers use music to communicate emotionally with their infants before they are able to understand language.

Introduction

Music is often referred to as the language of emotions, but there is considerable controversy as to whether music actually induces emotions directly in listeners and, if so, whether these musically induced emotions are the same as other emotional experiences. In this chapter, we examine evidence from neuroscience to explore these questions.

The question of meaning in music has been a subject of philosophical debate for a very long time.[1] Music is peculiar because in large part it appears to be a closed system, with musical meaning defined only in terms of music itself. Music can be referential in the sense of having an intended outside meaning (e.g. it can be about a thunderstorm, a war, or a love story), but this specific reference to events or things in the world is usually far from transparent to the listener. Music can also come to have meaning, in terms of convention (e.g. particular turns of phrase in Baroque music may be meaningful for listeners familiar with these conventions; particular *rags* may signal particular moods or moral qualities in Indian listeners educated in this tradition) or through association with events in the world (e.g. a particular song can signal bedtime for a child; lovers may associate a particular song with their courtship). However, conventional and associational referential meanings do not seem to account for the majority of meaningful responses to music. Rather, meaning appears to arise largely through the unfolding of sounds over time in relation to musical expectations.[2] In other words, to a large extent the meaning appears to be simply in the musical relations themselves.

Empirical psychomusicological research suggests that both adults and young children readily discriminate musical emotions.[3,4] The acoustic cues that differentiate emotions cover virtually all aspects of musical structure and include both structural (what is given by the composer) and performance characteristics.[5–8] For example, *sadness* is conveyed by quiet, slow, legato articulation and large deviations from metrical timing, whereas *happiness* or *joy* is conveyed by high-pitched, fast, staccato features and small variations from metrical timing.[9] However, music appears to express some emotions more precisely than others. Listeners generally agree on whether music is happy or sad, but there is less agreement when it comes to other emotions.[3,10] Acoustically, the differences between, for example, tenderness and sadness are rather subtle. According to Juslin,[9] both are quiet, have slow tempos, legato articulation, and large timing variations. Although they may differ in other subtle features, it does not appear that musical structure is set up to differentiate these emotions robustly. The notion that music may express readily only certain emotions must lead us to further question the nature of musical emotions, and how they relate to emotions in general.

It is likely surprising to psychologists to learn that some philosophers have argued that music does not express emotion, given the empirical data showing substantial agreement between listeners as to the emotion expressed in particular pieces of music. For example, a century and a half ago, Hanslick[11] proposed that music appreciation had nothing to do with emotion. Half a century ago, Langer[12] proposed that music bears some relation to emotion in that the rise and fall of tension in music, the interplay between uncertainty and resolution, mimics the time course of emotional experience. In this view, music does not express emotion, but we understand music through its similarity to emotional dynamics. On the other hand, Meyer[2] has argued that music does express emotions. According to his argument, musical emotions are induced through musical uncertainty, expectation for what will follow, and the way in which this uncertainty is resolved, similarly to how emotions are induced by other stimuli and events in the world.

Emotions can be classified in a number of ways. One approach is to extract the underlying dimensions of emotion, and to situate each specific emotion in this multi-dimensional space. Such analyses reveal two main dimensions of emotion: valence (negative to positive) and intensity (low to high).[13] Positive emotions are associated with approach behaviours and negative emotions with withdrawal behaviours. The ventromedial prefrontal cortex is thought to play a role in approach/withdrawal evaluations.[14] Although emotional processing in general tends to be more lateralized to the right than to the left,[15] there is also evidence that lateralization follows valence, with left prefrontal areas specialized for positive emotions and right prefrontal areas for negative emotions.[16–19] Despite the common view that 'music is the language of emotions', these models were developed without reference to musical stimuli. Music is an interesting stimulus in this regard, because in most cases it does not lead to overt approach or withdrawal behaviour. In fact, people often 'approach' sad music, in that they find it beautiful. Because music does not seem to be directly connected with approach/withdrawal behaviour, it is possible that music is *about* emotion, that music *communicates* emotional information, but that music does not directly *induce* emotions. One interesting question, then, is whether musical stimuli generate activity in the prefrontal cortex, and whether differential activation can be seen for music expressing different emotions.

There is currently much debate among psychologists and neuroscientists as to the nature of emotional experience in general and its relation to cognition, behaviour, consciousness, and the sense of self. According to one view, cognitive evaluation must take place first, and the emotional response is generated subsequent to this.[20] An opposite view posits that emotions correspond to unconscious activity in the autonomic nervous system, and that our conscious feelings are interpretations of this activity.[21,22] According to Damasio,[23] emotions are induced in a relatively small number of brain sites, most of which are below the cerebral cortex. These comprise various components of the limbic system that have long been implicated in emotion,[24] including the amygdala (particularly the central nucleus), the hypothalamus, and the basal forebrain. In this view, emotion evolved through mechanisms of evolutionary adaptation, and performs an essential role in life regulation.[25] An animal needs to know when to approach a stimulus or situation and when to avoid a stimulus or situation, and it is through innate emotional biases and learned emotional associations that the animal does this. Thus, according to Damasio,[26] all experiences are emotionally tagged and influence emotional reactions in future situations, even though the person or animal may no longer have conscious access to the original experience. For example, an early unpleasant experience with a dog may induce a fear response to dogs, even though the person may not remember the origin of the association.

Although it has been argued that music may be an evolutionary adaptation serving social group cohesion (e.g. Chapter 5, this volume), it has also been argued that music does not have any survival function at all.[27,28] However, if music engages both phylogenetically old and newer emotional systems, this would suggest that music evolved alongside emotion in humans. In this chapter, we will first explore whether music engages the autonomic nervous system, subcortical emotion networks, and cortical areas involved in the emotional processing of other types of stimuli. Second, we will consider whether emotional reactions to music are simply cultural conventions by asking whether and how infants process musical emotions.

Physiological responses to music

The subcortical emotion-processing parts of the brain affect the rest of the body through two basic mechanisms: the release of chemical molecules into the blood that act on various parts of the body; and the spread of neural activation to various brain centres and muscles. Through these mechanisms, the experience of an emotion is connected with a myriad of physiological responses, from muscle contractions, to changes in breathing and heart rate, to changes in blood flow in various parts of the body, to sweating. If music is simply about emotion, but does not induce emotion, one would not expect listening to music to activate the autonomic system, and physiological changes should not be evident. However, studies using both self-report[29] and direct measures of autonomic function[30,31] have now shown that listening to music does indeed produce autonomic changes associated with emotional processing. For example, adults report shivers down the spine, laughter, tears, and 'lump in the throat' as some physiological responses to music.[29]

Nyklicek *et al.*[31] presented listeners with musical excerpts expressing happiness, sadness, serenity, or agitation. These four emotions cover the extremes of an intensity/valence matrix: happiness and agitation are intense, whereas sadness and serenity are not; happiness and serenity are positively valenced, whereas sadness and agitation are negatively valenced. They found that changes in respiration clearly followed the intensity dimension. Respiration rate was higher, and inspiration and expiration times shorter, for the happy and agitated excerpts than for the sad and serene excerpts. This is consistent with the findings of Krumhansl,[30] who found respiration rate to be higher during fear and happy excerpts than during sad excerpts. The valence dimension, however, is less clearly seen in the autonomic measures. Using discriminant analysis, Nyklicek *et al.*[31] found that an arousal dimension accounted for 63 percent of the variance across a number of physiological variables related to respiration and cardiac function, whereas a dimension related to valence accounted for only 10 percent of the variance. Krumhansl[30] did find that respiration depth decreased more during happy excerpts than sad or fear excerpts, and that finger temperature decreased less for happy excerpts than for sad or fear excerpts. However, as a low-intensity, positive-valence emotion was not present in this study, it is difficult to determine definitively whether these measures reflect valence *per se*. It is clear, then, that music induces physiological changes consistent with the processing of emotional intensity, and perhaps also with emotional valence.

One approach to determining the relation between emotions induced by music and those induced through other means is to consider whether excerpts of music conveying different emotions produce distinctive autonomic signatures, and whether these signatures are consistent with emotions induced in other ways. However, there are inconsistencies in the autonomic signatures of specific emotions across studies using varying stimuli such as static visual stimuli, films, and directed facial action tasks. Thus, the idea that specific emotions are uniquely represented by specific autonomic patterns is still controversial.[22] Distinctive autonomic patterns for specific emotions are found when the directed facial action task is used.[32,33] However, there is little correspondence between these autonomic signatures and those found by Krumhansl[30] and Nyklicek *et al.*[31] For example, heart rate tends to be higher for sad than for happy facial actions and finger temperature does not differ, whereas heart rate tends to be slower for musically-induced sadness than for musically induced happiness, and finger temperature is higher for happy than for sad musical emotions. Facial action studies have been criticized as perhaps reflecting the difficulty of producing the facial expression rather than the emotion expressed.[34] In fact, many factors may influence the specific autonomic responses observed. Emotion is complex (e.g. there are many different kinds of happiness and fear) and differential effects may arise when overt responses are made or blocked.[35] Interestingly, musically induced autonomic responses are most consistent with those measured in studies employing manipulations that extend over time, such as watching a film or listening to a radio play.[30]

One difference between musical emotion and emotion arising in other domains is that overt action is not normally required in response to musical emotion. With development, people learn to control the overt expression of emotion to some extent. They may be able to stop themselves from uttering hurtful or angry words, but controlling their autonomic responses is more difficult. In the case of musical performers, however, feeling the music too much, and allowing autonomic responses free rein, could lead to an inability to perform. A singer with a tight throat will not have optimal sound control, and a violin player with sweaty, shaking fingers will not be able to play well. Damasio[23] gives a wonderful example of a pianist, Maria Joao, who claimed that she could cut off the flow of emotion to her body at will. Damasio's skepticism turned out to be unfounded, as laboratory tests confirmed that she could allow or block physiological responses during music listening. This leads to the interesting question of whether musical emotions are somehow more subject to cognitive control than other emotions, or whether all emotional autonomic responses can be controlled through learning.

In summary, music does induce emotion directly. However, more research is needed before we can answer the question of whether musical emotions have the same autonomic signatures as emotions induced in other situations. Similarly, we can only speculate at present as to whether musical emotions are more under cognitive control than emotions induced through other means.

Central nervous system responses to emotion in music

Music stimulates wide networks of bilateral activity across the brain, and specific areas within these networks appear to be specialized for the perception of various aspects of music such as melody, rhythm, and timbre (see Chapter 17, this volume). In particular, auditory cortex and frontal regions appear to be essential for musical processing.[36,37] Changes in pitch intervals and pitch contour are processed in auditory cortex even in the absence of attention,[38] and right frontal areas are activated during tasks involving pitch memory.[37] While right-hemisphere dominance is often found for pitch-based musical tasks (e.g. Chapter 16, this volume), laterality can be moved around by instruction (analytic vs holistic) and degree of musical training.[39,40] In contrast to the *perception* of music, much less is known about the networks for processing *emotional* aspects of music.

It is generally agreed that emotional processing of all types involves wide networks of central nervous system activity, including limbic and sensory areas as well as those related to cognition and consciousness.[41] However, consensus on the specific brain regions that are activated for each specific emotion is far from achieved.[22] This is likely due in part to the employment of different methodologies (e.g. PET, fMRI, EEG) across studies. However, it is also likely due to large effects on neural activity of the *contents* of emotional experience (e.g. which sensory systems are involved; the specific stimulus triggering the feelings), the salience of an emotion or extent to which the emotion is felt, different shadings of emotion within one category such as 'happiness', and, very importantly, differences between the induction of emotion, the feeling of emotion, and the conscious memory or discrimination of emotions. For example, the amygdala is strongly implicated in the induction and learning of fear responses,[41] but does not appear to be involved when fear states are recalled.[25]

Does emotion induced by music activate the same cortical structures as emotion induced by other stimuli? How is the processing of musical emotion affected by the contents of the stimulus? Given that research into the neural processing of emotion in music is just beginning, and given the lack of consensus on a model of emotional processing in general, definitive answers to these questions cannot be given. However, a few very interesting studies are providing a starting point. We will review here three approaches that have been taken. First, lesion cases involving impairment of musical ability can give a hint as to the brain regions involved. Second, PET imaging studies in normal adults who listen to music varying in its emotional content can also suggest the brain regions involved. Third, EEG studies examining general patterns of regional activation can be compared across conditions of musical and nonmusical induction of emotion.

Peretz *et al.*[42] presented a case study of a patient, IR, who showed a dissociation between perceptual and emotional processing of music, a dissociation that appears to parallel that found between the identification of faces and the processing of emotional expression in faces.[43] IR suffered bilateral damage to her auditory cortices, such that in the left hemisphere Heschl's gyrus and the anterior portion of the planum temporale are completely destroyed, the superior temporal gyrus is infracted, and the damage extends to adjoining regions. On the right, Heschl's gyrus and the planum temporale are spared, but the anterior and superior portions of the superior temporal gyrus are damaged, and there is a large frontal lesion that includes the precentral and inferior frontal gyri and part of the orbitofrontal gyri. Despite the left hemisphere damage, IR's language is normal. However, her musical perception abilities are severely damaged, and she is unable to recognize or discriminate melodies. Despite these perceptual deficits, IR is able to tell whether musical excerpts are happy or sad.[44] Furthermore, she can do this based only on the mode and tempo of the excerpts. Thus, at least in this one case, not only are music and language dissociated, but perceptual and emotional aspects of music are as well. Further research is needed, however, to determine whether IR uses modality-general emotional processing areas for determining musical emotion.

As an initial step into examining musical emotions, Blood *et al.*[45] used PET imaging to identify regions whose activity correlated with changes in musical stimuli along the consonance/dissonance dimension. This dimension is defined such that tones sounding pleasant or smooth together are said to be consonant whereas those sounding unpleasant or rough together are said to be dissonant.[46] Dissonance is interesting as it relies on the peripheral structure of the auditory system: the critical band structure of the basilar membrane[46,47] and the firing patterns in the auditory nerve (see Chapter 9, this volume). In brief, tones with harmonics that are close enough in frequency to be difficult to resolve along the tonotopic organization of the basilar membrane are perceived to be dissonant. Likely because of its peripheral origins, infants as young as two months of age are sensitive to this dimension, preferring to listen to simultaneous tones in consonant relations over those in dissonant relations.[48,49] This dimension is also critical to musical structure, as virtually all musical systems rely on dissonance to generate tension, and consonance to resolve that tension.

Blood *et al.*[45] found that some regions involved in affective processing from previous nonmusic studies were also activated with changes in consonance and dissonance, including right parahippocampal gyrus, right precuneus, bilateral orbitofrontal, medial subcallosal singulate, and right frontal polar regions. Furthermore, the degree of activation of certain areas differed across consonance and dissonance presentation, suggesting that music conveying positive and negative valence may have distinct cortical signatures. While interesting and suggestive, a caveat is necessary before making strong conclusions about musical emotional processing on the basis of this study. Although pleasant/unpleasant ratings correlated with activity in right parahippocampal gyrus, these dimensions did not correlate with ratings of happy/sad. Thus, while this study appears to capture something about the processing of musical valence, simply varying the amount of dissonance across a musical phrase is not the equivalent to inducing happiness or sadness. Dissonance without resolution likely corresponds more to irritation, which is a high-arousal negative emotion, rather than sadness, which is a low-arousal negative emotion. Furthermore, there is evidence for the cortical separation of consonance and dissonance from happiness and sadness. IR, described above, is unable to discriminate consonance and dissonance although she can discriminate happy from sad music.[50] In any case, this study suggests that musically induced emotions are processed in brain regions overlapping those involved in general emotional processing.

In a second study, Blood and Zatorre[51] explored intense positive emotional reactions to music by having each subject choose an except that gave them 'chills', and listen to it while PET responses were recorded. Compared to control conditions, the music induced increased cerebral blood flow in the left ventral striatum, dorsomedial midbrain areas, and paralimbic regions, areas that have been associated with euphoria, pleasant emotion, and cocaine administration in other studies. In addition, music listening was associated with decreases in blood flow to the amygdala, hippocampus, and ventral medial prefrontal cortex, which is also consistent with the experience of intense emotions in other contexts. In sum, these PET studies suggest that the experience of positive emotional responses to music activate the same brain circuits as positive emotions induced in other contexts.

There are two related lines of EEG research on emotion that may shed light on how musical emotion is processed in the brain. One line concerns the pattern of EEG activity that is observed in anterior regions during the processing of emotion. For example, a number of EEG studies have found evidence that frontal activation patterns differ across emotions.[16,17,52,53] A second line of research concerns the pattern of resting frontal EEG activity recorded during baseline or neutral states and its relation to individual differences in affective style or personality. In the personality literature, current thinking is that different personality styles emerge from how emotions are regulated.[16,17,52] For example, depression is thought to be characterized and maintained by an inability to experience positive affect; shyness and anxiety are thought to be characterized by an inability to regulate fear; sociability and extraversion are thought to be characterized and maintained by the experience of positive affect and the ability to control negative affect.

Interestingly, the pattern of resting frontal EEG activity has been shown to discriminate these various profiles, suggesting that the resting frontal EEG metric is indexing the predisposition to experience different affect states. This in turn suggests that the neural correlates of transient emotion may be similar to those shown for different personality types. One model has associated the intensity of emotion with overall amount of frontal activation.[54–56] For example, infants separated from their mothers show an increase in frontal activation.[57] A second model posits that emotions with positive valence, such as joy, interest, and happiness, show greater left than right activation whereas those with negative valence, such as fear, disgust, and sadness show greater right than left activation.[16,17,52,54,58] (It should also be noted that Blood *et al.*[45] also found that the positively valenced consonance excerpts tended to activate left frontal areas more than the negatively valenced dissonant excerpts.) Evidence for the frontal activation/emotion valence model has been found across a number of stimulus modalities including pictures, films, and taste[16,17,52] and in infants as well as in adults.[52] Furthermore, baseline or neutral EEG asymmetries have been linked to personality types, with outgoing individuals tending to exhibit greater relative left activation and shy individuals greater relative right activation.

Because the frontal activation/emotion valence model is based on the idea of a dichotomy between approach and withdraw behaviours with a deep evolutionary history, it is not clear a priori whether it would apply to music. However, we[56] found clear evidence that it holds for music as well. We presented listeners with music expressing emotions at the extremes of the intensity/valence matrix. Specifically, we used orchestral excerpts expressing joy (high intensity, positive valence), happiness (low intensity, positive valence), fear (high intensity, negative valence), and sadness (low intensity, negative valence) that had been rated by adults along the valence and intensity dimensions. Evidence was found supporting both the intensity and the frontal activation/emotion valence models. The measure of activation was the inverse of alpha band activity (8–13 Hz), as energy in this band decreases with increased activation.[58] The amount of frontal activation was correlated with adults' ratings of the intensity of their emotional response to the excerpts (from least to most intense: sad, happy, joy, fear), supporting the intensity model (Figure 20.1). Both joy and happiness showed greater relative left frontal activation whereas both fear and sadness showed greater relative right activation (Figure 20.1), supporting the frontal activation/emotion valence model. Thus, we[56] found evidence that emotion induced by music activates frontal circuits in the brain similar to those activated by other emotional stimuli.

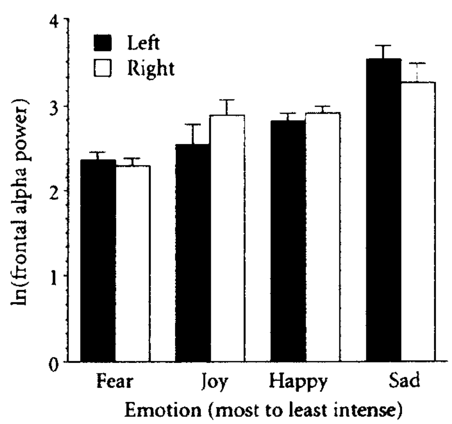

Figure 20.1 Differences among fear, joy, happy, and sad left and right frontal EEG alpha power. Note that EEG power is thought to be inversely related to activity, thus lower power reflects more activity. Overall activation is related to intensity, and positive emotions show greater relative left activation whereas negative emotions show greater relative right activation. Error bars represent the standard error of the mean. Reprinted with permission from Schmidt and Trainor.[56]

In summary, although there are rather few studies to date addressing how musical emotion is processed in the brain, the preliminary evidence suggests that, despite the fact that music has questionable evolutionary advantages, and despite the fact that music normally does not motivate approach or withdraw behaviours, music does appear to activate the same emotional circuits as other stimuli.

Development of emotional responses to music

The strongest argument that music is an important evolutionary adaptation arguably comes from the developmental perspective. Caregivers around the world sing to infants, and young infants are responsive to such music.[59] Singing directed at infants is rendered in a style that is distinct from other types of singing,[60,61] and infants prefer to listen to infant-directed over non-infant-directed renditions of the same song. The function of infant-directed singing remains somewhat elusive. However, one of the main theories is that caregivers use infant-directed singing to express emotional information, and to regulate their infant's state.[59 61] Young infants are, of course, not good at state regulation, and require intervention in order to calm down when upset. Mothers sing in two distinct styles, a lullaby style and a playsong style.[61–63] Adults can discriminate playsong and lullaby styles easily, and they rate playsongs as more rhythmic, brilliant, clipped, and smiling in character, and less soothing and airy than lullabies.[63] Furthermore, infants react differently when exposed to lullabies and playsongs, focussing their attention inward during the former and outward during the latter.[63] Thus, music has the power to affect an infant's state.

On the basis of the evidence that music is universally used in caretaking contexts for emotional expression and state regulation, and that infants react differently to different musical styles, it is possible that singing to infants serves an important adaptive function in development. Specifically, music may provide one route into learning about social interaction and self-regulation before infants understand any language.

Children are also able to distinguish different emotions in music. Cunningham and Sterling[64] showed that 4- to 6-year-olds could discriminate happy, sad, angry, and fearful musical excerpts. Trainor and Trehub[4] found that children as young as 4 years could reliably associate excerpts from Prokofiev's Peter and the Wolf and Saint Saens' Carnival of the Animals with pictures of the animals, giving emotion-laden justifications for their responses such as that the wolf excerpt sounded 'scary'.

The bases for early emotional reactions to music have not been investigated widely, but they likely involve interpretations based on pitch, tempo, and timbre characteristics of the music. One aspect of pitch structure has been investigated. As discussed previously, consonant intervals are associated with positive emotion and dissonant intervals with negative emotion. Using a visual looking paradigm in which infants control how long they listen to consonant vs dissonant chords by how long they fixate on a visual target, Trainor and colleagues[48,49] have demonstrated that infants as young as two months prefer to listen to consonant over dissonant musical intervals. These results complement previous findings that older infants also prefer consonance over dissonance.[65–67]

Given the behavioural evidence that young infants respond to the emotional content of music, the same question that we addressed previously with adults arises with infants: Does musical emotion stimulate the same brain circuits as other emotional experiences in infants? A number of EEG studies of nonmusical emotional processing in infants support the presence of frontal asymmetries related to valence.[52] For example, infants tend to show greater relative right frontal EEG activation during the processing of negatively valenced stimuli (i.e. faces displaying distress or fear, tastes that are sour) and greater relative left frontal EEG activation during the processing of positively valenced stimuli (i.e. faces displaying joy, smiling, and sweet tastes). As well, infants who show greater right than left resting frontal EEG activation tend to show heightened distress to novel events and maternal separation.

In order to test whether infants' EEG responses would show the same asymmetry effects for emotion induced by music, we[68] recently recorded EEG and ECG as 3-, 6-, 9-, and 12-month old infants listened to the joy, fear, and sad orchestral excerpts used in Ref. 56. Infant alpha band activity (4–8 Hz) was recorded, and activation was taken as the inverse of this measure. There were interesting changes across age (Figure 20.2). Compared to baseline, the presence of music significantly increased brain activity at 3 months of age, had little effect at 6 and 9 months of age, and significantly attenuated brain activity at 12 months of age (Figure 20.2),

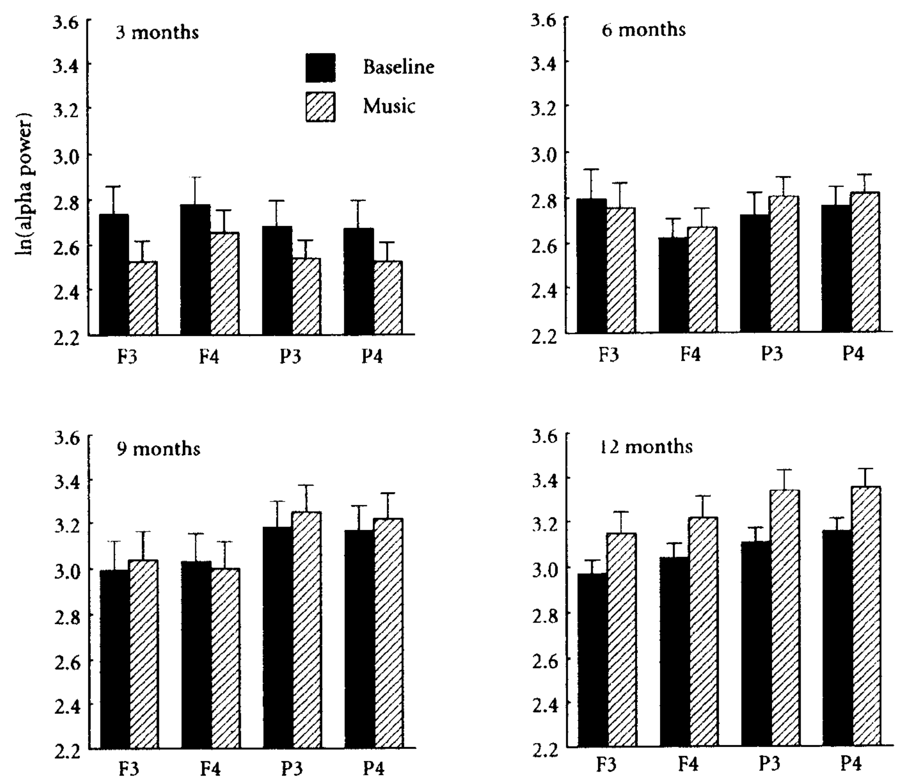

Figure 20.2 Infant alpha power for frontal (F3, F4) and parietal (P3, P4) regions and left (F3, P3) and right (F4, P4) hemispheres. Note that music has opposite effects compared to baseline at 3 and 12 months of age. Error bars represent the standard error of the mean. Reprinted with permission from Schmidt, Trainor, and Santesso.[68]

suggesting that music is having a calming effect by 12 months as infants are increasingly able to regulate their sensory input. However, no left/right asymmetries were found in any condition.

There are a number of possible reasons for the lack of asymmetric responses to musical emotion in infants. It is possible that musical emotion is processed differently than other emotions in infancy, but this would be surprising given the behavioural evidence for a central role of musical emotion in everyday infant caregiving activities. Another possibility is that the orchestral musical excerpts used were simply too complex for infants. While it is advantageous to use the same musical excerpts with infants and adults, this music is certainly not very similar to typical infant-directed singing. Still another explanation is that sufficient frontal lobe maturation for the cognitive appraisal of musical stimuli is not yet developed in the first year of life.

To address these possibilities, studies are underway to measure infant EEG with more ecologically valid stimuli. In particular, we are using vocal singing, infant-directed speech, and infant-directed singing conveying various emotions. At this point it is not possible to answer the questions of whether infants process musical emotions with similar brain circuits to those used for other emotions, or whether infants and adults use similar brain circuits to process musical emotion. However, methodologies now exist to ask these questions, and hopefully more data will be forthcoming.

Conclusions

The popular notion that music elicits powerful emotions appears to be close to the truth. That music is not only about emotion, but that it elicits emotion directly, can be seen clearly from the physiological responses it induces. The changes in heart rate, respiration rate, blood flow, and skin conductance are clear indications that music activates the phylogenetically old parts of the nervous system, and that music elicits a cascade of subconscious activity. Music also appears to activate the cortical systems associated with emotion, including circuits in the frontal lobes. Further research is needed, however, to address the questions of how discrete emotions are processed, and how various dimensions of emotion such as valence and intensity are encoded in the brain. There are many unanswered questions with respect to music, such as why happiness and sadness are so easily expressed in musical structure whereas emotions such as anger are so much more difficult to express.

Despite the fact that, for adults in the modern world, music does not command the same approach/withdrawal reactions as other emotion-laden stimuli, much evidence suggests that music does activate the same cortical, subcortical, and autonomic circuits as other emotions. Perhaps the answer to the puzzle of why music appears to activate the essential survival circuits of the nervous system—when music does not appear to serve any obvious survival function—lies in the evolution of development and child care. Human infants are particularly helpless for an extended period of time, and are reliant on their caregivers for survival. An emotional bond and the communication of positive and prohibitionary emotional information is essential for survival. Perhaps music evolved in order to further emotional communication between infants and caregivers. And perhaps infant-directed singing and infant-directed 'musical' speech[69] are intimately connected with approach and withdrawal behaviour on the part of the infant. Taking this one step further, as children develop other means of communication such as language, and as they learn to keep overt expressions of emotion under control, music may go 'underground'. Music still elicits emotion, but more direct and precise methods of emotional communication can occur with language. Perhaps, however, music retains a survival role in adults in that it allows the 'practice' of feeling emotions without having to risk the consequences of acting on these emotions. Thus, we are free to laugh and cry to music, to feel our heart race, to feel chills, and to hold our breath, and perhaps once again to feel like the infant who is exquisitely tuned to the emotion in its mother's voice.

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