

Chapter 7

The neuroscience of emotion in music

Jaak Panksepp and Colwyn Trevarthen

7.1 Overture: why humans move, and communicate, in musical–emotional ways

Music moves us. Its rhythms can make our bodies dance and its tones and melodies can stir emotions. It brings life to solitary thoughts and memories, can comfort and relieve loneliness, promote private or shared happiness, and engender feelings of deep sadness and loss. The sounds of music communicate emotions vividly in ways beyond the ability of words and most other forms of art. It can draw us together in affectionate intimacy, as in the first prosodic song-like conversations between mothers and infants. It can carry the volatile emotions of human attachments and disputes in folk songs and grand opera, and excite the passions of crowds on great social occasions.

These facts challenge contemporary cognitive and neural sciences. The psychobiology of music invites neuroscientists who study the emotional brain to unravel the neural nature of affective experience, and to seek entirely new visions of how the mind generates learning and memory—to reveal the nature of ‘meaning’. The science of communicative musicality—the dynamic forms and functions of bodily and vocal gestures—helps us enquire how the motivating impulses of music can tell compelling stories. This also leads us to ask how human music relates to our animal emotional heritage and the dynamic instinctual movements that communicate emotions.

Research on the emotional systems of animals is bringing us closer to explanations of the still mysterious aspects of human affective experiences, and hence the emotional power of music. Through unfathomed neurochemical responses in the brain, the sounds of music can bring joy and dull the jab of pain, as endogenous opioids and many other affective chemistries are recruited in musically entrained minds (Panksepp and Bernatzky 2002; Panksepp 2005c). With the aid of animal research on these emotional systems and how they interact with our cognitive abilities, we may find a new view of communicative musicality as a form of playful and endlessly inventive social behaviour that helps build, epigenetically, the social brains of our children, to facilitate mental and physical health and learning permeated by prosocial affects (Panksepp 2001, 2007b).

We review the evidence that the emotions of animals, their neurochemical basis and the body movements and vocalizations by which they are expressed, may reveal the deep sources of musical feeling in human beings. They help explain how music supports our social life, and how our musical preferences can define our ‘identity’ in society. We relate the comparative neuroscience of emotions to the rhythmic musicality of mother–infant communication. By considering the effects of brain injuries and genetic disorders in childrens’ brain development, we conclude that the acquired cognitive appreciation of music depends upon subcortical emotional systems that uniquely engage the cerebral hemispheres. We note the teaching and healing powers

of music, and relate communication of emotions in music to motives for cultural learning, especially to the evolution of language acquisition.

7.1.1 Musical meaning: the motives of musical culture

Although we can find expressive actions in animals that have rhythm and affective tone, the art of music, as most of us understand it, is uniquely human. We thrive in unique dancing, symbol-seeking, storytelling ways. Our communicative displays and performances exhibit the special multilevel time of human moving, with stepping feet, gesturing hands and visible and audible messages of exceptionally quick and versatile eyes, face and vocal system, all obedient to the slower rhythms of the whole gliding, swaying body, that becomes adept at generating affective narratives (Trevarthen 1999; see also Osborne, Chapter 15, this volume). Music is, from the beginning of a child's development, the polyrhythmic sound of the human body in adventurous and creative self-possessed activity that loves to communicate what it imagines. The times of its compositions span the range from fractions of a second to many minutes or hours (Kühl 2007; Trevarthen 2008a). As development proceeds, emotions come to express moments of wonder, longing, joy, rage, pride, fear or gentle affection, and these are woven into complexes of rhythm and melody that may become unforgettable and precious memories in the art of an historic culture, inseparable from rituals of many kinds that rule the way humans come to move and feel together (Turner 1982; Blacking 1995). We acquire intense and lasting preferences for particular pieces or kinds of music. Thus, music motivates our loyalties and place in society (MacDonald *et al.* 2002).

The precise relationship between emotions and cognitions in music remains obscure and controversial in modern psychology. Nevertheless, it is evident that, before its 'disembedded' information and structure is perceived with the aid of symbols and analytic thought, we know music first as lived and felt *experience* in the body, 'embedded' in intersubjective and cultural dynamics. This leads some who place high value on articulate rationality and symbolic communication in language to dismiss music as frills—inessential experiences, merely for entertainment. These scholars appear not to appreciate the real, everyday power of music to move us, and our need to share it (Sacks 2006).

Music blends readily with so many important dimensions of human lives in community, suggesting, on the contrary, it evolved as a prime facilitator of our social communication, our learning and the creation of cultural meaning (Blacking 1976, 1988, 1995; Bjørkvold 1992; Schubert 1996; Wallin, Merker and Brown 2000; Donald 2001; Mithen 2005; Cross 1999, 2007; Kühl 2007). Far from being an inconsequential emotional side-effect of the rational and informative consciousness of a Cartesian thinker, appreciating order in the measured tones of Apollo's lyre, the emotional response to a musical narrative is a cerebral force that drives and shapes memory, imagination and thinking in passionate Dionysian social encounters, as well as one for recreative escape from demanding tasks and enjoyment of good stories (Freeman 2000).

There are certain aspects of the so-called 'inner life'—physical or mental—which have formal properties similar to those of music—patterns of motion and rest, of tension and release, of agreement and disagreement, preparation, fulfilment, excitation, sudden change, etc.

Langer (1942, p. 228), quoted by Kühl (2007, p. 223)

Musical art is cultivated from the primary energy of human meaning-and-pleasure-seeking action, on the syntactic time base of which also rest the logical processes of reasoning and the mercurial references of language. That is how musical meaning is created and transmitted, and why it means so much.

Musical forms, it is true, readily become associated with particular cognitive representations or meanings in their enactive contexts, which Kühn (2007, p. 50) calls 'ur-semantics'. Its melodies and harmonies evoke images as well as emotions—remembered scenes and persons, adventures, reveries and relationships. It recalls special moments, an 'art of times' charged with emotions of interpersonal relating (Imberty 2000, 2005). But these important outward manifestations of musical meaning are never subordinate to, or just made of, any attachment to external particulars, even when its forms of expression are obedient to elaborate conventions of a musical literature, the score. Music remains 'about itself', and the emotions in its making (Trevathan 2008b; see Cross and Morley Chapter 5, and Rodrigues, Rodrigues and Correia Chapter 27, this volume).

Every human brain senses musical–emotional meanings many months before it becomes a facilitator of linguistic–propositional signs. For a child, musical expression is as natural as moving itself. If anything in the higher human brain has a genetically preordained evolutionary history, it is the fundamental urge to communicate in the temporal cadences of emotional movements, with endlessly creative protomusical dynamics, helping us understand why music is so widely treasured. At its very roots, musicality is part of our particular animal nature, an emotional–cognitive heritage that can be reconstituted into an endless variety of cultural pastries.

Musical meaning seems, indeed, to be the evolutionary and ontogenetic parent of linguistic terms and functions (Brown 2000, Mithen 2005), not just a frivolous younger relative. The first coos and word-like babblings of babies have musical/poetic structure matched by the intuitive parental encouragement that is attuned to them (Papoušek and Papoušek 1981, Stern *et al.* 1985, Papoušek 1994, Miall and Dissanayake 2003). In song, music is a natural partner for the cadenced language of poetry, the prosodic expression of emotions in dynamic intersubjective synchrony that Ivan Fonagy (2001) calls 'languages within language', the 'distant past still present in live speech'.

Language in its complexity enables the speaker to reflect mental content belonging to different phases of his emotional and intellectual development. In each creative verbal act—and in a wider sense, all speech acts are creative—we must first descend to deeper, thus earlier, ontogenetic and phylogenetic layers.

Fonagy (2001, pp. 687–688)

Moreover, the style and rhythmic pattern of music can define a person, role or group in society (MacDonald *et al.* 2002). Its rhythmic cycles facilitate the joint accomplishment of routine chores on which, we assume, the social cooperation that fostered the agricultural revolution in human prehistory was based, along with any talk about what was done. Once basic bodily needs are fulfilled, music, with dance, often becomes a central cultural passion that helps close knit groups of humans move and think together, sharing pleasurable narrations of vitality (Becker 2004; Benzon 2001; Schubert and McPherson 2006). The power of particular configurations of music, especially favourite or loved pieces, to inspire, heal or teach proves that musical expressions, and their communication, can engage the core mechanisms of the brain that regulate well-being in body and mind, and that guide the formation of self-confident associations and memories in affectionate relationships (Pratt and Spintge 1996; Pratt and Grocke 1999; Peretz and Zattore 2003; Klockars and Peltomaa 2007; Osborne, Chapter 25, this volume).

Whatever our evolutionary story may have been, we believe the instinctual–emotional core of the brain, essential for all these phenomena of music, has ancestry in the minds of living animals. Evidence from human brain mapping highlights how emotionally moving music resonates robustly within subcortical emotional circuits homologous with those of other species (Blood and Zatore 2001). Even if humans are the only species that makes and appreciates music, we find that the rhythms and basic sounds of musicality are evident in the sometimes long and intricate social displays of other animals (Rogers and Kaplan 2000; Wallin, Merker and Brown 2000, Section II). That, too, opens new paths to a neuroscience of music.

7.1.2 A possible evolution of human musicality

We believe that the evolutionary roots of musicality must lie in the repetitive rhythms and emotions at the source of moving. Especially important are the emotional sounds by which birds and mammals communicate. We mammals are social creatures who depend critically on resonance with the inner purposes and concerns of others. At times we need to call on others for help, request affective sustenance and companionship, and share the essential tasks of mating and care for defenceless young. Musical dynamics resemble the dynamics of emotive movements and feelings evident in the ritual behaviours of communicating animals (Darwin 1872; Tinbergen 1951; MacLean 1990; Rogers and Kaplan 2000). Throughout our evolutionary journey, as in our infancy, the sounds of emotions connected us and guided our relationships and collaborations, and our actions in harmonious, joyful play, and in conflict or distress (Dissanayake 2000; Mithen 2005).

We, along with Merlin Donald (2001) and Ole Köhl (2007), believe that an innate rhythmic musicality provides the prosodic background for all of our lyrical urges to communicate affectively, however artificial and sophisticated the techniques of that communication and its symbolization may become; however disembodied or abstracted from bodily activity and its perceived context. Young children and adolescents advertise their enthusiasm for life, their creativity, self-confidence, longing and sociability, in displays of musical exuberance (Bjørkvold 1992; Miller 2000; MacDonald *et al.* 2002; Miell, MacDonald and Hargreaves 2005; Custodero 2005; Schubert and McPherson 2006). An infant just six months old can demonstrate infectious glee in the performance of the actions of a clapping song, looking for affectionate praise (Trevarthen 2002; and see Gratier and Danon, Chapter 14, this volume), and a musical joke can be appreciated, indeed performed, two months before that (Stern 1990, 1999; Malloch 1999, p. 47), when an infant is beginning to show flirtatious coyness (Reddy 2003; Reddy and Trevarthen 2004). Untold young children have expressed their epic affective imaginations in dramatic song, with no audience but Mother Nature.

It appears likely, therefore, that human musicality evolved as an evolutionary exaptation of social-emotional systems that became the medium by which our ancestors harmoniously coordinated not only intimate engagements, but also ambitious group activities, as in hunting large and dangerous animals, harvesting crops, defending small family groups in a hostile world, and teaching the young (Cross, 2007; Brandt Chapter 3, Cross and Morley Chapter 5, this volume). Ellen Dissanayake suggests that the intimate communication between helpless but intelligent infants and their sensitive and responsive mothers was the place where human musicality first grew, and that this was the source of other cooperative social uses of expressive behaviour (Dissanayake 2000; Dissanayake, Chapters 2 and 24, this volume). These possibilities (Roederer 1984; Storr 1992; Wallin, Merker and Brown 2000, Sections III and IV; Mithen 2005), may forever be lost in a psycho-evolutionary past, the traces of which cannot be deciphered with any certainty (Wallin 1991; see Cross and Morley, Chapter 5, this volume). However, the study of the emotional dynamics of other living creatures may eventually help reveal the affective evolutionary and developmental foundations of human musicality.

7.1.3 The comparative psychobiology of musicality

First, we assume that the intuitive affective responses of humans to music involve brain processes still active in other living animals. Thus, most mammals and birds may exhibit *protomusicality*, and we propose that we might be able to probe their living brain systems and emotional activities as Rosetta stones to decipher our psycho-evolutionary past in detail (Panksepp 1998a, b, 2003; see Merker Chapter 4, Cross and Morley Chapter 5, and Turner and Ioannides Chapter 8, this volume).

For instance, the brain mechanisms for birdsong appear to grow like the brain mechanisms for practice and learning of speech in children. Research on the parts of the brain of a bird necessary for the performance, hearing and learning of song has revealed that young birds must hear and experiment with motor performances of their own song if they are to learn from a tutor how to maintain the more elaborate adult song and how to discriminate the songs of other individuals, skills that establish them as mature members of a community (Marler and Doupe 2000). This active vocal learning of expressions of self and others, and its brain mechanisms, has been compared to an infant learning to speak (Doupe and Kuhl 1999). In neither case is the neural mechanism of motivation for subjective and intersubjective regulation of emotional expression in the voice well understood.

Evidence from experiments designed to clarify the associations between core emotional processes and conscious experiences of music supports the ideas of Clynes (1977, 1995) and Krumhansl (1997) concerning the appreciation of 'sentic forms', i.e., sensed movement shapes, organized temporally in the brain, with different emotional force and narrative significance. These forms appear to obey universal dynamic principles of emotional movements, and they regulate the power and efficiency of instinctual actions in animals (Clynes 1982; Lee *et al.* 1999; Lee 2005; Schögler and Trevarthen 2007; Lee and Schögler, Chapter 6, this volume). All healthy animal movements are rhythmic, with qualities of power and grace. These features become accentuated in emotional communication, most conspicuously in human music.

Animals and humans communicate with motor organs that are adapted for both regulation of selective consciousness by orienting and focusing special sense organs, and for emotional communication (Trevarthen 2001). Especially expressive of human intentions, interests and feelings are the hands, eyes, face and voice—movements which give conscious guidance to volatile inner states or 'motives' (MacLean 1990; Scherer 1986; Goldin-Meadow and McNeill 1999; Zei Pollermann 2002). Thus, while accepting the greater complexity of our human actions and experience, we would relate human song and music making, as well as the rhythmic rituals of communication by gesture and dance, to the instinctive affiliative calls, vocal expressions of passion and displays of intentions in body movement of other highly social animals (Darwin 1872; Wallin, Merker and Brown 2000, Section III; see Dissanayake Chapter 2, Brandt Chapter 3, Merker Chapter 4, and Pavlicevic and Ansdell Chapter 16, this volume).

It is through melodic emotional intonations that our species first masters one of its most productive skills—how to chat (Bateson 1979; Trevarthen 1974, 1993, 1998, 2005). In the last trimester of gestation preferences for and recognitions of rhythmic and melodious vocalizations emerge, long before any sense is made of propositional speech (Fifer and Moon 1995; Lecanuet 1996). The development of musical responsiveness can be monitored by musically induced changes in spontaneous rhythmic movements of infants (Condon and Sander 1974; Condon 1979; Trevarthen 1999; Mazokopaki and Kugiumutzakis, Chapter 9, this volume), as well as by recording accompanying autonomic changes. For instance, Chang and Trehub (1977) report that before infants are six months old, they exhibit heart-rate changes when melodic contours are changed. Zentner and Kagan (1996) report visual avoidance in 4-month-old infants exposed to dissonant harmonic stimuli, which is not evident in response to consonant stimuli.

Young babies are riveted by the melodious flow of a mother's lullaby, and their bodies become entrained to musical rhythms. They are profoundly sensitive to the contingency and authenticity of a communicative partner's rhythm of expression, and to the sympathy of the feelings expressed by gestural movements and in tone of voice (Murray and Trevarthen 1985; Nadel *et al.* 1999; Robb 1999, Trevarthen 1995, 2005; Powers and Trevarthen Chapter 10, Marwick and Murray Chapter 13, Gratier and Danon Chapter 14, this volume).

7.1.4 **Why, then, is human ‘musicality’ so mysterious, and such a new idea? How have we deluded ourselves?**

Some writers have asked why the essential emotional musicality of our nature has been so neglected in scientific analysis of human life and the human mind and brain (Cross 1999, 2003; Mithen 2005). Such blind spots in our established scientific ways of thinking, may reflect the over-intellectualized views of mind engendered by the computer model-based cognitive revolution. The primal embodiment of human communication seems largely forgotten, except in recent developmental studies. This culturally promoted neglect contrasts with the more cohesive intersubjective social practices and beliefs in the East (Becker 2004) and in Africa (Blacking 1988, Frøshaug and Aahus 1995; see Woodward and Bannan Chapter 21, and Rodrigues, Rodrigues and Correia Chapter 27, this volume). Likewise, much modern brain science is not concerned with the affective mechanisms of the brain that give music meaning.

To overcome this bias, a plausible scientific theory of innate or intuitive musicality is needed. Thus, we advance the view that human musicality represents a distinct motive system, related to the imaginative capacity of other social animals for cooperative moving and practical affective living in community. Among humans, this motive energizes a parable-making imagination of mind that Turner (1996) calls ‘literary’, but which is equally ‘poetic’, ‘musical’ or ‘theatrical’ (Brandt Chapter 3, and Cross and Morley Chapter 5, this volume).

Brown (2000), Donald (2001) and Stokoe (2001) have proposed that *mimesis*—the expressive use of the body and gesture to portray recalled or imagined thoughts and experiences as projects in engagement with the world—was the first truly human form of communication. The symbolic power of the art of gestural rhythm and lyrical–affective expressions are clearly evident in traditional classic Indian dance forms (Hejmadi *et al.* 2000), and are nascent in the performative talents of toddlers with their highly energetic bodies (Bjørkvold 1992; Custodero 2005). This dynamic, fully human mode of liveliness, with its prosocial humour and joy, deserves to be recollected and revalued in intellectualized subcultures of the West (Bjørkvold 1992; Frøshaug and Aahus 1995). Without appreciating this socializing aliveness, we may generate inadequate visions of the human brain, and hence the human mind, which may promote cultural degeneration.

7.2 **The socio-emotional psychobiology of music**

7.2.1 **Animal calls and mother–infant dialogues are musical, and serve learning**

Two phenomena indicate that the neurobiological foundations of music are social–emotional. First, music-like vocal communications between animals serve essential social functions. In many species, the amount of vocal activity that has evolved to advertise sexual attractiveness and generate social arousal is phenomenal (Bradbury and Vehrencamp 1998; Hauser 1996). Second, the emotional use of the voice is the primary medium by which mothers coax their babies into the human cultural world. Here, there is something new, beyond the regulation of sexual reproduction and ‘inclusive fitness’.

The melodious chat of infant directed speech and dancing musical games and songs requires the invention and learning of rhythms, affective melodies, and intersubjective harmonies that tell of possible adventures, and that connect an infant’s awareness to the cultural and epigenetic history of its parents’ community going back many generations (see Gratier and Danon, Chapter 14, this volume). Their rhythms and prosodic sounds, charged with emotion, are made meaningful in imaginative ways. Infants respond to their mothers precisely with their own vocal

expressions in 'protoconversations'. Even on their own, without adult assistance, infants in groups can express their feelings and can regulate the drama and meaning of their relationships in musical ways (Bradley, Chapter 12, this volume).

A momentous affective–cognitive transition was achieved in the evolution of mind when mothers and infants started to communicate in this way (Fernald 1992a, b; Papoušek *et al.* 1991; Dissanayake 2000). This affect-sharing is well-described as the 'cradle of thought' (Hobson 2002). It is likely to have evolved in association with the executive thinking required to regulate the use of clever hands, and their incorporation into gestural communication of subtle tides of self-sensing and intention (Donald 2001; Pollick and de Waal 2007). Indeed, newborn infants make many complex and highly expressive hand movements, which remain, as yet, little studied (Trevarthen 1986; Rönnqvist and Hofsten 1994).

The ancestral dynamics motivating the social communication of vitality and well-being in animal-made sound may be essential preparation in our brains for the emergence of human communicative musicality and musical meaning, and then for language (Kühl 2007; Brandt Chapter 3, Cross and Morley Chapter 5, this volume). Even rats and mice produce emotionally attractive sounds during joyous, playful and sexual interactions (Panksepp and Burgdorf 2003; Holy and Guo 2005). Our close ancestors lived in arboreal canopies where sound was an efficient way to coordinate cohesive group activities, to periodically reinforce and re-establish social bonds, and to sustain dominance/submission patterns in ways that minimized physical injury (Hauser 2000, Seyfarth and Cheney 2003; also see Richman's [1987] descriptions of the social 'songs' of Gelada monkeys, and the report on the songs of gibbons recorded by Merker and Cox [1999]).

Although the emotional calls of other primates are more stereotyped than those of humans (Marshall and Marshall 1976; Hauser 2000), they have evolved to mediate subtle messages of vital importance in the maintenance of cooperative groups (see the social functions of the nuanced calls of vervet monkeys revealed in the work of Cheney and Seyfarth 1990). They transmit information for the collective awareness of opportunities or dangers, as well as individual identity and rank in the group (Seyfarth and Cheney 2003; Merker, Chapter 4, this volume). Such primal urges for prosodic social communication may have served as an essential foundation for the evolution of human musicality that led to language.

Musicality certainly both aids learning of non-musical skills, and uses them. New information is comparatively easily acquired when encoded in affective musical forms (Panksepp and Bernatzky 2002; Shepard 1999)—an effect evident even in profoundly retarded children (Farnsworth 1969; Merker and Wallin 2001; Wigram and Elefant, Chapter 19, this volume). Musical training can apparently strengthen brain functions at many morphological levels (Schlaug *et al.* 2005; Turner and Ioannides, Chapter 8, this volume), including the subcortical systems for hearing speech and music (Musacchia *et al.* 2007). Indeed, the bodily movement facilitated by music, as well as the accompanying autonomic and mood changes, show how powerfully music can engage with the core regulation of complex movements, conscious awareness, concepts and memories useful for survival in a human community. Affective states reflect the energetic states, or 'vitality affects' (Stern 1999), of the nervous system that are not explained by information-processing metaphors (Ciompi and Panksepp 2005; Panksepp 2005a, b).

The priority of dynamic 'relational affects' (Stern 1993) over cognition remains a salient aspect of our personal and cultural lives. As Adam Smith (1777/1982) said, musical sounds, with theatre or dance, are 'our most pleasurable inventions', and many tens of thousands will seek to commune in musical environments that the socially talented can create. By contrast, serious cognitive communications will rarely attract a massive audience, even if the speaker is eminent in the field.

7.2.2 Human musicality and physical exuberance of interactive play: important distinctions

One fundamental brain process for helping weave individuals into the social fabric among mammals, and some birds, is social play (Bekoff and Byers 1998; Burghardt 2005; Panksepp 1998a). Rough-and-tumble physical play and/or chase-and-dodge teasing play are intrinsic, experientially refined faculties of every mammalian species, which help promote social affiliations and epigenetic development of fully social brains.

In the first formal experimental analysis of physical play of children, without the biasing presence of material toys, we investigated whether the presence of music (in this case joyous Irish jigs) would energize this most fundamental form of social engagement (Scott and Panksepp 2003). Surprisingly, it did not. Neither did it facilitate laughter, even though an intensification of various dancing locomotor effects was evident. Thus, primitive physical playful engagements were not unconditionally facilitated, but expressive dancing movements were (see Mazokopaki and Kugiumtzakis, Chapter 9, this volume). Music was apparently communicating at a different level from the primitive childhood urges for physical play, perhaps partly because such play is largely subcortically organized (Panksepp *et al.* 1994).

However, there are many forms of play. It seems music is a medium by which the young humans first indulge in a potentiality for the drama of imaginative and imitative symbolic play (Turner 1974, 1982), for the art and story-making imaginativeness in *self*-expression that may be unique to our species, and that may be first evident in mother–infant sing-along interactions (Dissanayake 2000; Eckerdal and Merker, Chapter 11, this volume). This encourages us to make two critical distinctions concerning the complexity of human emotionality and musicality—distinctions that mark an evolutionary advance from the primal sociability of other mammals.

First, musicality seems directly linked to the highly articulated adventurousness of thought in metaphor that guides all forms of human acting and attending, which is enhanced aesthetically by intrinsic emotions. Second, and secondarily, music seeks the complexity of learned ritual and acquires narrations of rhythm and melody (Kühl 2007; Trevarthen 2008b), eventually involving artificial subtleties of technique and remembering or ‘notating’ (Brandt, Chapter 3; Merker, Chapter 4, this volume). If so, we again must consider musicality to be a profoundly foundational and evolutionarily rooted aspect of Art, and of what is uniquely cognitive and rational in human nature—a liminal or transitional activity working creatively between physical exuberance and rationality (Turner 1983).

7.2.3 Musical passions: Intrinsic emotional assessment of the communicated meanings or values of moving

All integrated actions and interests of animals have emotional control, balancing the anticipated risks and benefits of behaving. These emotional valuations have evolved settings of sensitivity and expressive form that define a set of adaptive affective neural systems, operating with different specialized neurotransmitter codes; these systems are integrated with the bodily hormone-producing systems that diffuse information through the body to regulate and protect the vital state of its somatic and visceral organs (Panksepp 1998a).

Diverse affective neural systems are the regulators of physiological resources and prospective awareness in control of moving and sensing in the present (Bernstein 1967; Jeannerod 1994; Lee 1998, 2005; Lee and Schögler, Chapter 6, this volume). The motor regulating system, with its emotions, animates the recalling of experiences of moving, the imagining of an active future, and the dreaming of impossible reflections on the intentions and emotions of moving (Solms 1997; Levin 2004). It links the time-keeping functions and neurodynamics of brainstem dopamine and

other emotional action systems (Holstege *et al.* 1996) with the more cognitively conscious environment–sensing–learning and thoughtful regions of the forebrain.

The felt emotions of music probably arise in this motivating core of the brain, which includes the basic emotional brain systems that have been identified using localized electrical stimulation of various mammalian brains (Panksepp 1998a). These emotional networks mediate receptive SEEKING, FEAR of danger, RAGE when access to resources are compromised, LUST to insure reproduction, CARE to assure nurturance of the young, PANIC/separation distress by which young signal caretakers when they are lost, physical play to promote exercise of social skills and to build prosocial brains, all interacting with a core SELF that helps represent a primordial neurosymbolic representation of the body within the brain. The last four social emotions are especially important in promoting and shaping creative communal activities (Panksepp 1998a).¹

These systems promote all instinctual actions and valuation of the world. At the psychological level, they reflect our basic affective capacities—the ability to engage in the world with great interest, to become enraged if our freedom of action is limited, to become scared if our actions lead to personal harm, to feel lust, care and joy for social engagement, and to feel the sting of pain when losing things we value, especially people we love (Panksepp 1998a, 2003c). All of these feelings, or shades of them, can be evoked by music.

Many recent findings on how music modulates or recruits activity in the human brain (recently reviewed by Peretz and Zatorre 2003) are outside the scope of this chapter, since they have not sought to identify dynamic emotional effects and regulations in the brain, but have been exclusively concerned with practical musical perception and cognition and the acquisition of musical skills.

Even as certain rhythmic elements of music that convey affective change are being clarified (Gabrielsson 1995; Peretz *et al.* 1998), only preliminary evidence from human brain imaging informs how brain emotional changes facilitate music appreciation (Blood and Zatorre 2001). We may need to categorize emotions differently, taking into consideration the many emergent emotions that arise when basic emotions interact with cognitive structures. The language-based, state-describing ‘categorical affects’ (such as happy, sad, angry, disgusted) may not optimally define the emotions experienced in music. It is also necessary to focus on the dynamic and the relational affects that characterize the sensations of energy and grace in the movement and interpersonal messages of emotionally charged gestures (Stern 1993, 1999).

Music communicates feeling qualities, transmitted with distinctive activation contours, which are, ‘captured by such kinetic terms as ‘crescendo,’ ‘decrescendo,’ ‘fading,’ ‘exploding,’ ‘bursting,’ ‘elongated,’ ‘fleeting,’ ‘pulsing,’ ‘wavering,’ ‘effortful,’ ‘easy,’ and so on’ (Stern 1993, p. 206). In Stern’s terms, these give ‘vitality forms’ to the emotions, which are probably homologous with the ‘sentic forms’ described in musical expression of more categorical feelings by Manfred Clynes (Clynes 1995; Clynes and Nettheim 1982). These can be related to the affective neuroscience of basic emotions (Panksepp 1998a). Some musical intervals are consistently perceived by listeners, who are asked to put words to their emotional qualities, as ‘monotonous,’ ‘sad,’ ‘joyful,’ ‘disharmonious,’ ‘calm,’ ‘whole,’ ‘resolute,’ etc., terms which can be related to different ways the body moves—‘up–down,’ ‘out–in,’ ‘tense–relaxed,’ ‘repulse–receive,’ ‘asymmetric–symmetric,’

¹ Capitalizations designate basic emotional systems, to (i) avoid part/whole confusions, (ii) alert readers to the claim that these may be necessary brain systems for those types of emotional behaviours and feelings, although by no means sufficient for all of the emotional manifestations that may arise from those systems in real-world activities, and (iii) highlight that specific psychobehavioural brain systems are the referents of these labels.

'straight-round', 'cheerful-gloomy' (Krantz 2007). The musical intervals clearly evoke the same ideas of different qualities or efforts of moving in different listeners.

Although there is evidence from electroencephalography (EEG) that brain activity is affected by music (e.g., Petsche 1996, Sarnthein *et al.* 1997), we still know little about how affective properties of music modify human brain activity (e.g., Hodges 1995; Panksepp and Bekkedal 1997; Panksepp and Bernatzky 2002). Presumably, links will be found between the regulatory evaluations of emotions and the rhythmic modulations of motor activity, with their multimodal prospective perceptual control (Lee and Schöglger, Chapter 6, this volume). It is clear that a wide array of brain activities become involved in the production and perception of music (Kühl 2007; Turner and Ioannides, Chapter 8, this volume).

7.2.4 Musical narrative or 'adventure': the intentional core of the brain, and its time

Rhythmic processes, paced by adaptable biological clocks that respond to environmental contingencies, are a conspicuous feature of organized tissues, including neural nets, and especially in the regulation of vital functions serving metabolism and the energy economy of the body—most obviously in beating of the heart and breathing, but also in the control of diurnal rhythms of sleep and wakefulness, and anticipations of the changing seasons (Bernardi and Sleight 2007). All animals locomote by moving their bodies rhythmically, and the rhythms of flying birds, scurrying mice, plodding elephants, walking, trotting or galloping horses, or gibbons swinging between the trees invite imitation in music.

Music depends upon the rhythmic measure of expressive movements in time, and the tensions created by combining rhythms (Osborne, Chapter 15, this volume). The 'architecture' and 'narration' of moving psychological time is manifested in the measured rhythms of human action, experience and communication, real or imagined—with its emotional qualities and their relation to vital functions of the body (Trevarthen 2008a). These psychobiological processes are measured in three bands or ranges of physical or scientific time: (1) for the felt and imagined 'extended present' (from 10 seconds to years); (2) for the conscious 'psychological present' (Stern 2004), with its rhythmic motor control coupled to the physiological rhythms of breathing and variations in heart rate (0.3 to 7 seconds); and (3) for 'reflex experiences' and 'just noticeable differences' too fast to be regulated by movements that are prospectively controlled in awareness (5 to 200 milliseconds). (For detail and the sources of this information see Trevarthen 1999).

The time of musical narrative, which Imberty (2000) calls the macrostructure or 'story-without-words' of music, is related to the times of expressive behaviour that form 'protonarrative envelopes' of intuitive vocal and gestural play between infants and their mothers (Stern 1985, 1995; Malloch 1999). The period corresponding to a stanza or verse of 20 to 40 seconds may be regulated in the brain, as gamma waves or parasympathetic cycles, to control autonomic functions of the heart and breathing. It continues through sleep to produce fluctuating rates of breathing and heartbeat, as well as electrical activity of the cerebral cortex that might be related to the rehearsal and consolidation of memories in dreaming (Delamont *et al.* 1999). In wakefulness the narrative cycle is charged and modulated for intersubjective meaning with the 'microtonal' and 'microtemporal' variations of emotion that express urgency and facility in skilled control of moving within the voice of a singer or the playing fingers of an instrumental performer, and in the hearing of a listener (Imberty 1981, 2000; Gabrielsson and Juslin 1996; Juslin 1997, 2001; Kühl, 2007; Osborne, Chapter 15, this volume). Music can assist the synchronization of physiological functions of respiration and heart activity and bring improvement in locomotor activity, and it can improve cognitive and memory processes by brain synchronization.

Despite individual differences in subjective preferences, the physiological effects of music are often predictable (Bernardi and Sleight 2007).

7.2.5 Musical sympathy: the intersubjectivity of movements and emotions

This anatomy and physiology of intentions (i.e., emotional intentions-in-action; see Panksepp 2003c) help regulate social collaboration intersubjectively. The core emotions of vertebrate brains have evolved to resonate among emotionally interacting individuals. They constitute the primordial core self (Panksepp 1998a, b). They establish *self-other* defining motivations in higher medial regions of the brain implicated in the development of both *self-referential* information processing and sociable *self-awareness* (Schore 1994; Northoff *et al.* 2006; Schilbach *et al.* 2006).

In the course of the evolutionary process that established social communication of intentions and feelings between animal *selves*, polymodal areas of the higher regions of the forebrain come to act in resonance with the intentions and feelings of other subjects, constituting what are called 'mirror' representations, which however do more than reflect what other subjects are intending to do (Gallese 2001; Gallese, Keysers and Rizzolatti 2004; Jeannerod 2004; Rizzolatti *et al.* 2006; Molnar-Szakacs and Overy 2006; Bråten 2007). Being emotionally controlled, these *other-within-self* intersubjective representations establish sympathetic resonances, and intersubjective contagions, probably by intrinsic affective systems situated much lower than the neocortex (Watt and Pincus 2004), making complementary adjustments to the intelligence and feelings expressed in gestures of other bodies and sensed by sight, sound and touch through neocortical processes that are epigenetically programmed by experience. This cerebral machinery of emotional *self-other* awareness (Thompson 2001; Reddy 2003) is the ancestor of much more than a 'language acquisition device' (Rizzolatti and Arbib 1998); it is the motivator of sociocultural existence and its moral foundations, and of each individual's urge from infancy to learn cultural skills, including those of language (Trevorthen 2004; Bråten and Trevorthen 2007).

7.2.6 An interlude: the genetics of the musical and social mind in Williams syndrome

Certain neurologically impaired children, the development of whose intellectual competence is seriously compromised, retain musical and social desires (Sacks 2007). This is evident in Williams syndrome children, who show musical talents and social/linguistic urges in spite of severe handicaps in areas of spatial comprehension and performance (Mervis *et al.* 1999). Children who have this rare developmental disorder, affecting both boys and girls with a prevalence of about 1 in 20,000, are outgoing and socially joyous and communicative though handicapped in movement and practical intelligence. Their unique cluster of symptoms appear to arise from anomalies in crucial growth-regulating genes (for a summary, see Peterson and Panksepp 2004). Williams children are usually mentally retarded, with an overall IQ of about 50 (that in some exceptional individuals approaches normality). They are deficient in visuospatial skills, but often perform well above their mental age in auditory-social skills of speech and music. Their characteristic physical, physiological and psychological features were first recognized as a distinct syndrome in 1961, by Dr J.C.P. Williams, a New Zealand pediatrician (Williams *et al.* 1961). The genetics of this disorder have been well detailed, with three to five major disrupted genes identified in the 7q11.23 stretch of chromosome 7 (Nickerson *et al.* 1995; Frangiskakis *et al.* 1996; Peoples *et al.* 1996). Apparently, these defective genes impair forebrain development and prevent normal spatial-cognitive skills from emerging, while releasing other perceptuomotor and social abilities more dependent on hearing (Jernigan *et al.* 1993; Bellugi 2001).

Although Williams children will never be able to read, write or do mathematics well, many have a remarkable knack for music, dance and performance, along with simple but highly embellished forms of storytelling. Williams children, unlike most children with autism, are eager to communicate their feelings in expressive ways. The cognitive strengths and weaknesses of Williams children are also quite distinct from those of Down's children. Williams children may have difficulty walking down the stairs, but be able to coordinate superbly the movements needed to play a musical instrument. Even though they cannot draw an elephant or bicycle, they can describe them vividly. To their descriptions of everyday objects, they often add a richness of detail and emotional meaning rarely matched by normally developing children, who seem prosaic or reserved by comparison (for overview, see Bellugi 2001).

Many Williams children, like some children with autism, exhibit perfect pitch perception—the ability to identify, and name, an isolated sound exactly as a note in a musical scale (Levitin and Bellugi 1998). This ability is lost in most adults but can be learned (or re-learned) as a skill. Paradoxically, perception of the absolute pitch level of an isolated note, rather than a sensibility for the relative pitch of musical notes in groups, which adults generally find easier, is demonstrated in infants (Saffran and Griepentrog 2001). Evidently children with developmental brain disorders fail to make a reorganization of pitch awareness; this is presumably linked to learned discrimination of meaning-rich pitch transitions in speech. Although the analytical skills of Williams children for musical form may not be of a high order, they are remarkably engaged with music or song as a means of emotional expression in sound (Don *et al.* 1999; Hopyan *et al.* 2001). The psychological phenotypes of these children highlight how dramatically social emotionality, musicality and language urges go together in the brain.

In other cases of abnormal brain development, for instance in the presence of severe higher cerebral impairments that would lead to persistent vegetative states in adults, a well cared-for child, with essentially no higher brain regions intact, can remain emotionally conscious, and their distress can still be soothed by music and by the musical expressions of caring others (Shewmon *et al.* 1999; Merker 2006). We commonly accept that normal musical appreciation is totally interpenetrant with certain cognitive abilities, but there is a fundamental musicality that seems to be more basic, supporting the hypothesis that our love of music is strongly linked to our genetic heritage of core emotional and motivational processes (see Wigram and Elefant, Chapter 19, this volume, for an example of the power of musical communication to win over profound mental handicap, and Robarts, Chapter 17, this volume, for accounts of how music therapy can ameliorate emotional havoc caused by abuse).

7.3 The neuroscience of music

7.3.1 Visualizing the brain processes of intersubjective sympathy

Electroencephalic recordings have shown that 8-week-old infants' brains respond to the sight of a woman's face with activity in cortical zones that will later acquire socially important concepts and skills; skills not only to recognize different people and their personal characteristics by their face or voice, but to see and hear their communicative gestures and to articulate and comprehend expressive language (Tzourio-Mazoyer *et al.* 2002). Babies' brains become active in the same regions as are aroused in adults when they understand one another's speech and hand gestures (Willems and Hagoort 2007). Research on adult music learners shows that brain regions associated with musical skills are comparable to those involved in acquiring speech and language (Schlaug *et al.* 2005; Molnar-Szakacs and Overy 2006; Turner and Ioannides, Chapter 8, this volume).

This stunning information on the 'embodiment' of human communicative talents is radically changing our view of how higher brain functions emerge. But the location and organisation of

networks of the human brain that generate the whole-person emotional ‘time in the mind’—of moving, thinking, remembering and imagining (Clynes 1982; Clynes and Nettheim 1982; Wittmann and Pöppel 1999) remain obscure. This lack is a large part of the mystery surrounding musicality and its biology.

7.3.2 Affective neuroscience, cognitive neuropsychology of the hemispheres and consciousness of music

Our spontaneously musical nature suggests that the higher information-processing activities of the human mind are not essential for arousing our affective experiences (Zajonc 2004, Sacks 2006, 2007). Affective consciousness is sufficiently distinct from cognitive consciousness (highly interactive as they obviously are), that if we conflate the two, we can easily misunderstand how core affective states are created in the brain (Ciompi and Panksepp 2005; Panksepp 2003a, b, 2005a, b), and how higher emotions emerge through cognitive interactions. The effects of differently located cerebral injuries confirm this view.

The widespread brain mechanisms of musicality can be distorted or confused by brain injury (Sacks 2007), but can also survive the severe depletion of the cognitive brain. Maurice Ravel, who lost his ability to write music following left hemisphere trauma, continued to conceive and enjoy music, as have many other individuals with similar brain damage (Peretz *et al.* 1998). Other people with restricted brain lesions have lost many intellectual and executive functions but retained musical appreciation (Peretz and Zatorre 2005; Stewart *et al.* 2006). Musicality is intrinsically asymmetric in the human brain. Most of us have, since infancy, spontaneously appreciated vocal prosody and enjoyed music more with our right than with our left hemispheres. We engage with the emotions of others more with our right than left hemispheres (for references see Trevarthen 1984, 1996; Storr 1992; Schore 1994; Siegel 1999). These asymmetries are also evident in the ways we gesture with our hands to express our thoughts and feelings (Kimura 1982; MacNeilage 1999).

Infants are, of course, born with more affective than cognitive competence. We come into the world with our dynamic and interpersonal mental and emotional life, concentrated more in deep subcortical emotional and affective limbic forebrain systems, intensely active (Chugani 1998; Panksepp 1998b). Hearing music or speech is not just ‘in’ the auditory neocortex. The infant brain subcortical systems of voice appreciation are certainly more active than the auditory cortex, and can be compared directly to the vocal auditory systems in other species (Ploog 1992; Hauser, 2000). An obligatory brainstem waystation for auditory processing, the inferior colliculus of the midbrain roof, lies over the periaqueductal grey (PAG), where all emotional systems converge on a coherent self-representation of the organism—a primordial core consciousness (Damasio 1999; Panksepp 1998a, b; Merker 2005). That brain region clearly mediates affective processes in all mammals (Bagri *et al.* 1992). This is where a mother’s voice may leave its first affective imprints, and it is evidently active in the refinement of hearing that comes with practice of musicianship (Musacchia *et al.* 2007). It is richly endowed with opiate receptors (Panksepp and Bishop 1981) that help mediate social attachments including our atunements to voices of those we love, and hence, by parallel reasoning, to certain types of music (Panksepp 1995) (Figure 7.1).

7.3.3 Cerebral asymmetry of musical awareness, and its emotional foundations

Before they begin to develop their more propositional, linguistically defined left-hemisphere abilities, babies exhibit a right-hemisphere dominance that is prepared to engage and interact emotionally with loving caretakers (Schore 1994, 1998). Young babies, at 3 months, show greater brain arousal effects of music than 12-month olds, and as in adults, positive and negative

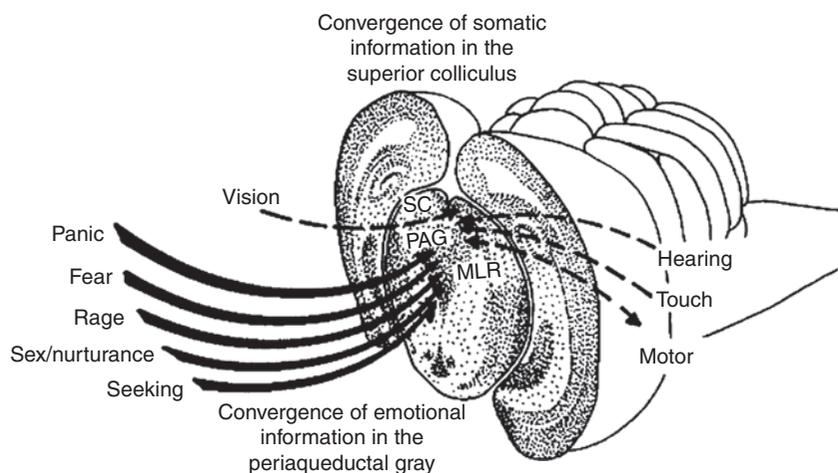


Fig. 7.1 Convergence of the major emotional systems on the self-coordinating mechanism of the periaqueductal grey (PAG) in the midbrain.

emotions tend to arouse respectively the left and right hemisphere functions of infants (Trainor and Schmidt 2003).

The neurology of music (e.g., Critchley and Henson 1977; Steinberg 1995; Sacks 2007) has long recognized that the right emotional–prosodic hemisphere (Bogen 1969) is more influential than the linguistic–propositional left hemisphere in affective musical appreciation and expression (Peretz 1990; Perry *et al.* 1999; Zatorre 1984). It appears that the aspects of music that are more analytical and learned rely more on developmental potentialities of the left neocortex (Peretz 1990; Sergent *et al.* 1992), which acquires a special relationship with more focused and serially patterned movements (Kimura 1982). Thus spontaneous, affective musical responsivity is typically mediated more by the right hemisphere of the adult brain, suggesting an intimate relationship throughout development between dynamic, self-regulating emotional functions and musical processes.

There is a long ancestry of asymmetry in physiological and socio-emotional regulations of vertebrate brains (Bradshaw and Rogers 1993; Quaranta *et al.* 2007), the right side of the brain as far back as the amphibia (Malashichev and Rogers 2002) demonstrating a specialization for ‘trophotropic’ energy-conserving regulation of well-being, while the left is adapted more for ‘ergotropic’ energy expending engagement with the environment. These asymmetries are innate in human infants and function throughout life in both self-regulations and the emotional control of communication and personality (Davidson and Hugdahl 1995; Trevarthen 1996; Davidson 2001; Tucker 2001). They are rooted in asymmetric systems of the brainstem associated with the hypothalamo–pituitary–adrenal (HPA) the sympathetic–adrenal medullary (SAM) regulations, both coupling neurochemical and hormonal mediators, the HPA being concerned with a ‘distress’ or ‘conservation withdrawal’ response to a threat of stress, the SAM being an active ‘effort’ or system that promotes fleeing and fighting (Trevarthen *et al.* 2006).

7.3.4 How the musical–emotional brain grows: prenatal origins of intrinsic motives and feelings

‘Primordial motive systems appear in subcortical and limbic systems of the embryo before the cerebral cortex. These are presumed to continue to guide the growth of a child’s brain after birth. We propose

that an 'intrinsic motive formation' (IMF) is assembled prenatally and is ready at birth to share emotion with caregivers for regulation of the child's cortical development, upon which cultural cognition and learning depend.

Trevarthen and Aitken (1994, p. 599)

Our core time sense and control of effort in whole-body biomechanics—integrating a flexible trunk with head, arms and legs—is given its rhythmic control, coherence and regulation of energy by a widespread Intrinsic Motive Formation (IMF) (Trevarthen and Aitken 1994) (Figure 7.2). The IMF is defined as the assembly of nerve systems that activates, integrates and steers movements and aims the perceptual guidance of the moving body, coordinating the limbs and balancing the whole in relation to the inertial forces of the parts and the forces arising from contact with the external media, selecting goals by aiming the focus of awareness of diverse sensory organs (Trevarthen and Aitken 1994, 2003; Trevarthen 1997). It arises in the brainstem, the core of the embryonic central nervous system, mapping all representations of the motor organs and sensory fields somatotopically, i.e., in relation to the polarity and symmetry of the body (Trevarthen 1985). The integrative anatomy of the IMF, and its rhythmic activity, is established in the embryonic brain before sensory or motor nerves connect the organic vitality and implicit intelligence of the body with conditions in the outside world. The fetal brain is already 'intentional' in this experience-seeking sense (Zoia *et al.* 2007).

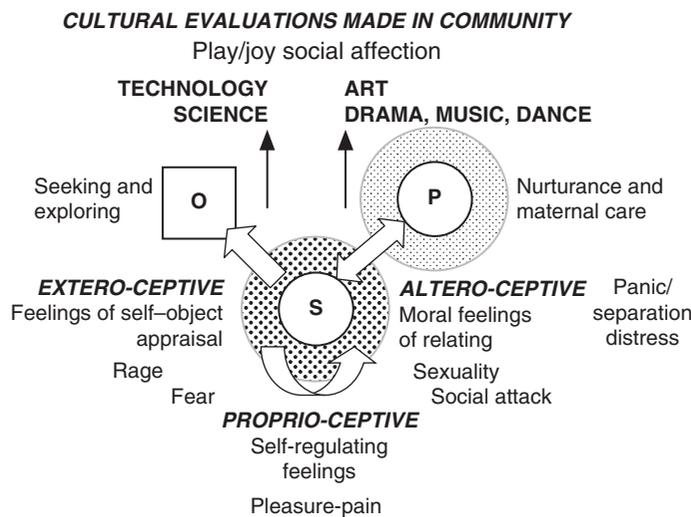


Fig. 7.2 The intrinsic motive formation (Trevarthen and Aitken 1994) coordinates the vital states of human being and directs engagements of the embodied Self (S) with the environment. It has three different systems of emotional regulation of movements and perceptions: *proprioceptive* for feelings of the well-being of the body; *exteroceptive* for feelings of engagement with the objects (O) of the physical world; and *alteroceptive* for sympathetic feelings for the intentions and emotions of other persons (P). Human musical activities and experiences are part of the cultural process that develops both the technology and art of a historical community by communication of both the practical and emotional aspects of all these three regulatory systems (Trevarthen 1998, 2005). The basic emotions systems (Panksepp 1998a) are indicated as they relate to the body, to the experience of physical objects (on the left) or to communication with other subjects (on the right).

As the cerebral hemispheres mature to regulate the dynamics of conscious imagination and thought, and the detailed experience of both speech and music (Callan *et al.* 2006), they do so within the integrative control of the subcortical brain (Merker 2006). Every motor impulse or plan is evaluated emotionally with regard to its value for the present and future well-being of the organism. The IMF projections also modulate and collaborate with the immense integrative powers of the cerebellum, which gives precision and order to the timing of motor actions throughout musculoskeletal mechanisms of the whole body in movement, and under prospective control by all senses (Bell *et al.* 1997; Bell 2001). Through the integration of the IMF infrastructure, in concert with the affective system of the brain (Panksepp 1998a) multisensory information is given meaning in relation to the antecedent intentions, attentions and conscious experiences of the maturing infrastructure of the self (Merker 2005, 2006; Northoff *et al.* 2006).

7.3.5 Tracing musicality beneath cognition in the subcortical reaches of the human brain/mind

Much classical work in human neuropsychology comes from the study of brain damaged people. However, it is now possible to image the effects of brain activity in people without brain damage, including asymmetries of hemispheric involvement, which are correlated with musically induced affective experiences (Turner and Ioannides, Chapter 8, this volume). For instance, pleasurable and disagreeable aspects of consonance and dissonance in sounds or melodies are related to the arousal of activity in particular regions of the brain (Blood *et al.* 1999). Positron emission tomography (PET) imaging has proved impressive in highlighting the degree to which activity in subcortical areas of the human brain, that are homologous with those long implicated in animal emotionality, contribute to high levels of affect (e.g., Blood and Zatorre 2001). A worthy hypothesis is that music, while serving active communication of dynamic and affective processes in the mind and involving all levels of the brain to do so, depends on the arousal of basic emotional feelings in the core self associated with brainstem neural processing directly concerned with the neuro-humoral regulation of bodily states (Panksepp 1998b). It is unlikely that high-level cognitive processes of environmental awareness and intricate acquired skills can, alone, support the affective states of musical appreciation or their instinctive communication. Rewards of music may arise partly from the brain dopamine systems (Menon and Levitin 2005) that integrate the search for and appreciation of reward (Alcaro *et al.* 2007).

In addition to correlative analysis of brain changes, it is important to directly manipulate brain chemistries to get some appreciation for the causal infrastructure of feelings evoked by music. By using pharmaceuticals such as naloxone and naltrexone to modify synaptic transmission in brain opioid systems, investigators have already evaluated whether the opioid pleasure system of the brain helps mediate music appreciation. As already noted, the emotions evoked by music can be markedly diminished by opioid blockade (Goldstein 1980), while modest doses of major tranquillizers that suppress peripheral autonomic effects have not been found to diminish the emotional impact of music (Harrer and Harrer 1977, p. 216). Although such work remains in its infancy, our working hypothesis is that the general emotional effects may arise from changes in central biogenic amine systems, while the more specific moods and emotions are conveyed by intrinsic neuropeptide systems. Likewise, the literature on the effects of music on many bodily systems and processes is growing steadily (e.g., Pratt and Grocke 1999; Kreutz *et al.* 2004; Stefano *et al.* 2004; Klockars and Peltomaa 2007), and in section 7.3.7 we will consider work on peak emotional experiences with music that produce the bodily feeling of chills.

Overall, the localization of the deep-seated generators of emotion by functional brain imaging will require more sensitive and more responsive techniques than we now possess (Turner and Ioannides, Chapter 8, this volume). It is already clear that basic emotional arousal

results in neural resonances that are very widely distributed in the brain, and fast changing. Emotional circuits resemble tree-like structures, with trunks and roots in subcortical areas, and widespread canopies in cortical regions (Panksepp 1998a) (Figure 7.3). Accordingly, we presume music accesses emotional systems at many levels and has whole-body effects.

Skilled auditory processing of musical information requires many higher reaches of the brain, linking auditory temporal lobe inputs into amygdala and basal ganglia (as in the motivational circuitry of the nucleus accumbens), and involving frontal, parietal and limbic–cingulate cortical regions. These function in close association with the refined integration of motor dynamics and their multimodal sensory regulation in the cerebellum (Blood *et al.* 1999; Blood and Zattore 2001; Menon and Levitin 2005).

Many higher brain systems are essential for the cultivated appreciation of music, and for skilled performance, as well as for the complex information processing that is essential for musical intelligence, as measured by psychometric tests (Penhune *et al.* 1999; Peretz *et al.* 1994; Peretz and Zattore 2003). As one becomes a skilled musician, the brain control of music appreciation

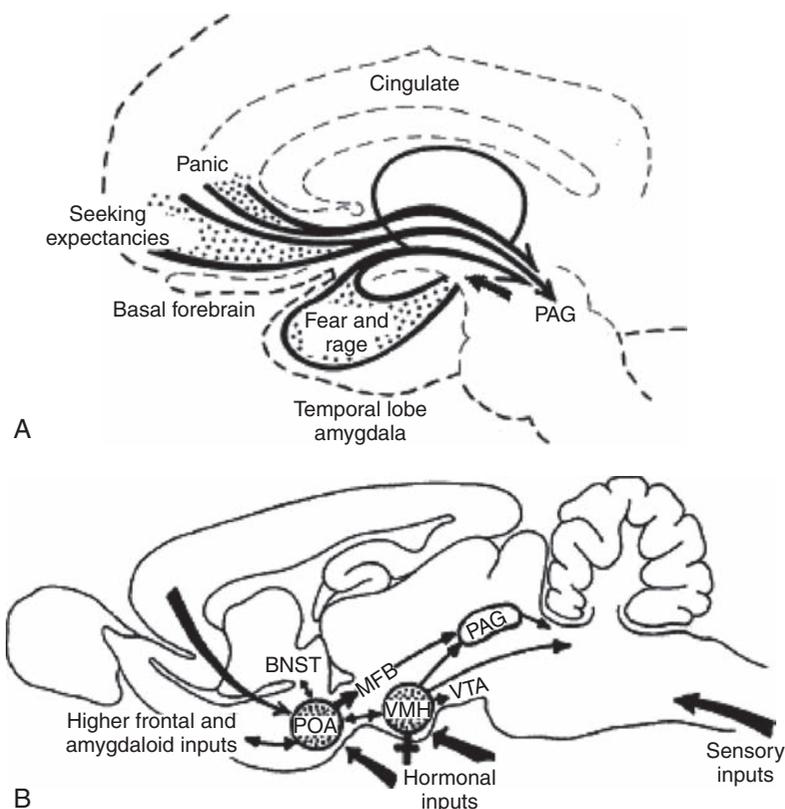


Fig. 7.3 Emotions mediate between body and mind, regulating intentions, awareness and wellbeing, in the individual and with the community. Schematic of subcortical emotional systems of the mammalian brain (A), and one system responsible for regulating sexual behaviour in the rodent brain (B). BNST = bed nucleus of the stria terminalis; POA = pre-optic area; VMH = ventromedial nucleus of the hypothalamus; VTA = ventral tegmental area; MFB = medial forebrain bundle; PAG = periaqueductal grey (Panksepp 1998).

apparently shifts from right hemispheric affective to more left hemisphere analytical skills (Zatorre 1984).

In short, there can be no restricted brain ‘module’ of musical intelligence, but many widespread emotional systems that transmit the affective qualities of music throughout the brain. Thus, although there are bound to be specific evolutionary adaptations for musical appreciation in higher regions of the brain, the emotional power of music may be largely dependent on premusical emotional adaptations of the brain. The ability of a musical pulse to arouse a desire for bodily movements and to induce various autonomic changes is congruent with the powerful subcortical influences of music (Hodges 1995; Blood and Zattore 2001).

7.3.6 Music-induced emotions in the real time of brain activity

Skilled musicians and everyday listeners alike recognize the basic emotional and motivating content of music (e.g., Juslin 1997, 2001; Robazza *et al.* 1994; Imberty 2000). Even little children are quite adept at identifying emotional themes in music (Terwogt and Van Grinsven 1991). Most humans, whether adults or children, distinguish four named emotions that move our bodies differently—happiness, sadness, anger and fear—and these same emotions can easily be conveyed as distinct by the dynamics and tonality of music with considerable confidence. Moreover, performing musicians can also improvise dynamic ‘portraits’ of these individual emotions (Gabrielsson and Juslin 1996; Gabrielsson and Lindstroem 1995; Juslin 1997, 2001; Nielzen and Cesarec 1982). However, understanding these foundations is just a beginning, because it is clear that movement in music conveys a rich panoply of ‘vitality affects’, as defined by Stern (1999), that are related to the feelings of the body moving in itself and in the world (Krantz 2007; Lee and Schögler, Chapter 6, this volume).

While a great body of data claiming to trace steps in musical information processing by the brain has now been published (for a summary and discussion, see Peretz and Zatorre 2003), little work has been conducted to determine how the motivations and emotions of music instigate and modify higher cerebral neuronal activities as they come about, keeping in mind that functional Magnetic Resonance Imaging (fMRI) and PET studies do not directly monitor nerve cell firings, recording only changes of local metabolic physiologies in cortical tissues, and with limited spatial and temporal resolution. Electroencephalography (EEG) or magnetoencephalography (MEG) are the only techniques that can directly monitor real-time electrical activity of the human brain (Petsche *et al.* 1998; Turner and Ioannides, Chapter 8, this volume).

To help fill that gap, Panksepp and Bekkedal (1997) evaluated topographic (EEG) changes to standardized ‘sad’ and ‘happy’ selections from Terwogt and Van Grinsven (1991). These optimal segments of happy and sad music were repeated about 30 times using a topographic analysis of the whole cerebral surface. The repetition allowed them to use the sensitive event-related desynchronization and synchronization (ERD and ERS) algorithms developed by Pfurtscheller *et al.* (1990).

The results were variable. Within the sensitive alpha range (8–12 Hz), there were only modest tendencies, primarily in females, for happy music to induce less cortical arousal (more synchronizations) and sad music to produce more arousal (more desynchronizations), especially in the posterior, multimodal sensory regions of the cortex (Panksepp and Bekkedal 1997). In males, this pattern was reversed. However, subjects had no personal ‘relationships’ with these musical selections. When repeated with self-selected ‘loved’ music, the brain changes were more robust. Happy music produced more robust event-related synchronizations (i.e., decreased cortical arousal) and sad music produced more event-related desynchronizations (i.e., increased cortical arousal). This pattern is reasonable from the perspective that during sad emotional states, people

have more cognitive and anxiety-provoking issues to dwell on, which would be expected to facilitate ERDs. During happy feelings (of relaxation), no such cognitive arousal is needed. However, there was no clearly sustained laterality effect comparable to those described by Davidson (1992), and in studies of simple repeated tones and melodies (Breitling *et al.* 1987). It appears that music engages with episodic rather than declarative memory systems, which construct personal life histories of emotion-rich experiences (Tulving and Markowitsch 1998), and thus it may 'play' creatively and socially between the hemispheres, engaging and enhancing the use of their complementary mental aptitudes (Turner 1982, 1983).

It is to be emphasized that cortical measures such as the above give no good indication of what may be transpiring in subneocortical emotional systems—the primary-process generators for affective states (Liotti and Panksepp 2004; Panksepp 2000a, 2005a). For that, we need to use less direct estimates of neural activity, such as the PET and fMRI approaches already noted (Blood and Zatorre 2001; Menon and Levitin 2005).

7.3.7 Bodily feelings from music: with a focus on 'chills'

Substantial experimental work has examined the effects of music on the regulations inside the body (for a summary of early work on effects on autonomic function see Critchley and Henson 1977; for more recent research, see Hodges 1995; Steinberg 1995). The effects on bodily dynamics are expected simply because music so effectively arouses and changes both the autonomic functions and emotional feelings that are associated with preparations for purposeful moving (Jeannerod 1994). However, it is increasingly clear that different individuals commonly show different physiological responses to music (Nyklicek *et al.* 1997; VanderArk and Ely 1992), confirming that personality or habits of motivation, and episodic memory for embodied life events, are critical components of how people respond to music and to other socio-emotional experiences. This variability, so common in human psychophysiology and brain imaging work (Barrett 2006), may clarify why some people prefer affective engagement, and others more detached cognitive perspectives to music appreciation (Storr 1992). The intimate interpersonal 'sympathetic' regulations of vital bodily functions shape, from before birth, our differences in social boldness or timidity, in self-confidence and the need for intimate support, even for twins conceived with the same genes (Piontelli 2002; Trevarthen *et al.* 2006); they presumably also affect our musicality and tastes in music.

One dramatic and consistent bodily effect induced by music is the feeling of shivers or chills many people experience when they are intensely moved, as by emotionally powerful music (Sloboda 1991), especially bittersweet songs of unrequited love and longing, and of patriotic pride arising from the commemoration of lost warriors, which may reflect group-cohesion dynamics (Panksepp 1995). These feelings are experienced as intense and desirable peak affective experiences. Parenthetically, other highly aversive chill-evoking sounds, such as fingernails scraping across a blackboard (Halper *et al.* 1986), are presumably generated by different brain response than the chills discussed here.

There is substantial individual variability in the incidence of this response. Typically, people experience more chills to musical selections with which they have a pre-existing emotional relationship, but chills can be rapidly established to new emotionally moving music, suggesting it is a response based on attachments that individuals develop to the music they enjoy. Some people—perhaps those who are less socially emotional and more alexithymic—rarely experience musically evoked chills. Most, however, delight in the experience. Females exhibit the response more than males, perhaps because the response is dependent on 'interior' socio-emotional sensitivities, and they are more likely to have such experiences from music they experience

as sad, expressive of loneliness or loss, rather than music they experience as happy and more sociable (Panksepp 1995).

High-pitched sustained crescendos are ideal stimuli for evoking chills. One hypothesis is that an influential acoustic property that triggers the response is that the sound resembles the separation cry of babies—the primal care soliciting signal that attracts social care and attention, especially by mothers. Musically evoked chills may arise from the resonance of our brain separation-distress systems that mediate the painful emotional impact of social loss (Panksepp 1981, 2003c). In part, the affective impact of this response may reflect homeostatic thermoregulatory adjustments triggered by separation experiences, which promote motivational urgency for social reunion. The evolutionary roots of social motivation are partly linked to thermoregulatory networks of the brain (Panksepp 1998a). The sound of a lost child sends chilly shivers down our spine. This may promote urges for reunion and the re-establishment of social warmth with body-to-body contact (Figure 7.4). Indeed, positively valenced music to the left ear (and right brain) tends to increase body temperature, while negatively valenced music has the opposite effect (McFarland and Kennison 1989). Musical performances that evoke chills blend a wistful sense of loss with the possibility of reunion and redemption. Such aesthetic experiences remind us of our humanness—our profound social attachments and loving dependencies, our relatedness to other people and nature.

Since pharmacologically induced opiate receptor blockades can reduce the incidence of chills (Goldstein 1980), the chill response is partly due to changes in endogenous opioid activity in the brain. The directionality remains ambiguous—the chill experience may follow either a rush of endorphins or, conversely, perhaps a precipitous decline in endogenous opioid activity (Panksepp 1995). A recent PET imaging study of the human brain indicates that sadness is accompanied by opioid activity in the limbic system (Zubieta *et al.* 2003). Blood and Zatorre's (2001) work has highlighted abundant arousal in the socio-emotional limbic regions of the brain during chill-evoking music. Positive correlations were evident to positive affective responses in subcortical emotion-regulating regions, such as the ventral striatum and midbrain periaqueductal gray regions.

Work on the psychobiology of chills has barely begun, but is beginning to captivate a new generation of investigators who are working out the physiological nature of the response and the aspects of music most likely to evoke such feelings (Craig 2005; Grewe *et al.* 2007; Guhn *et al.* 2007). Beside helping illuminate the nature of musical aesthetics, such musically induced brain responses could clarify the addictive nature of music (Figure 7.5).

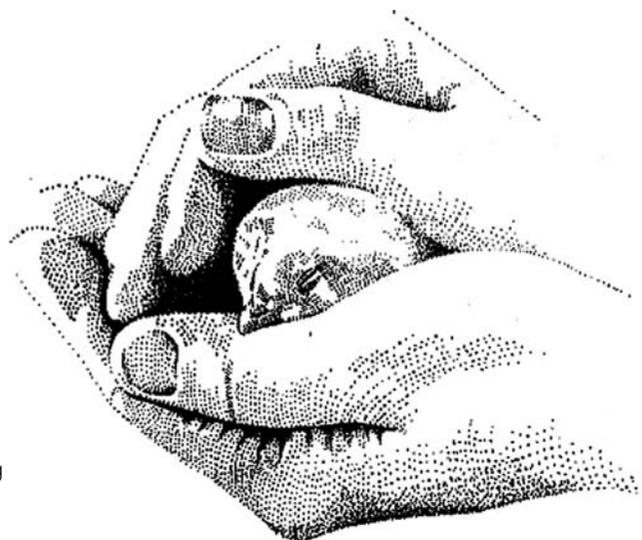


Fig. 7.4 A chick reacts to being held in warm hands by falling asleep.

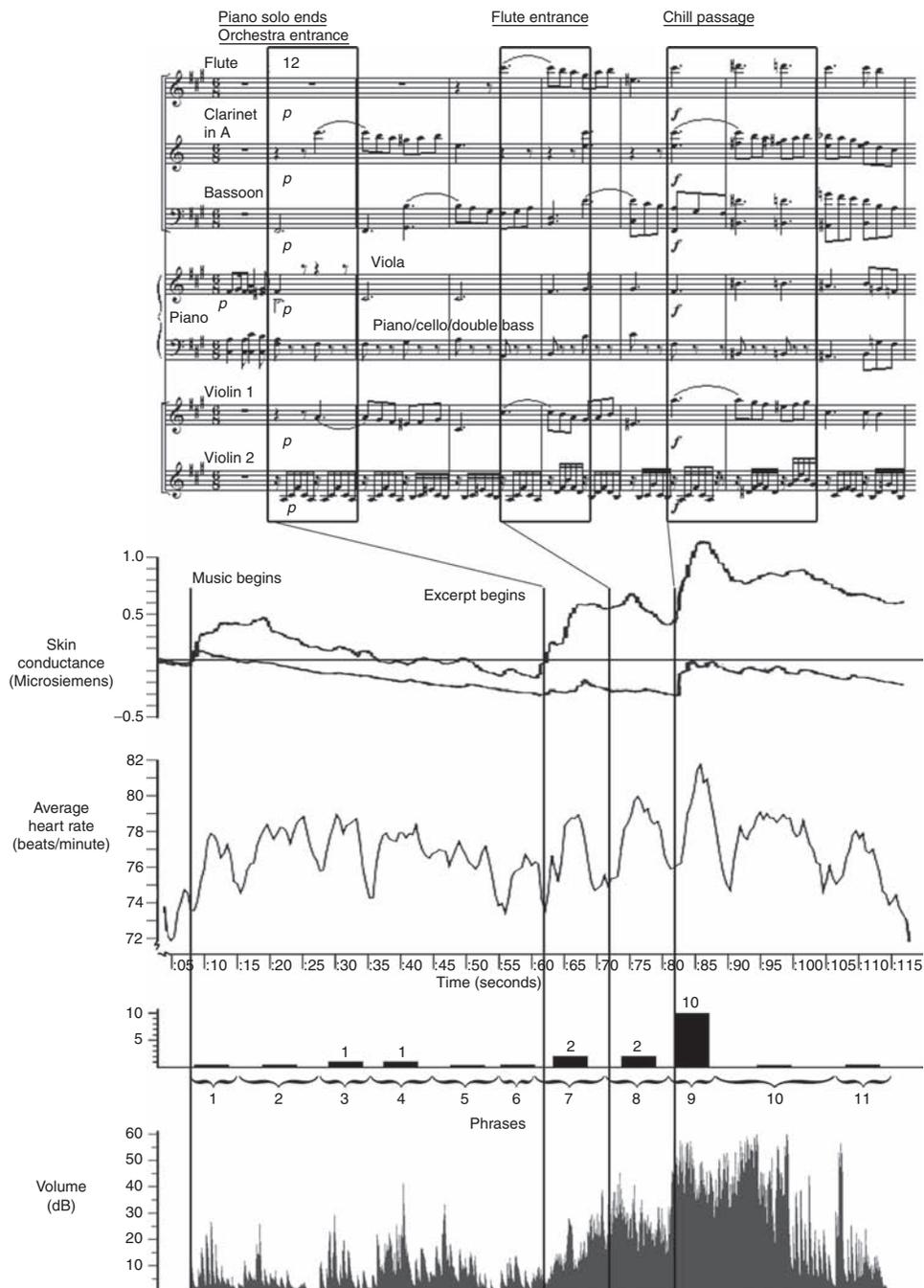


Fig. 7.5 From Guhn *et al.* 2007. Excerpt from Mozart's Piano Concerto (K488), 2nd movement, measures 11–18; including the passage, measures 16–17 (top graphic) where listeners experienced 'chills'. Mean skin conductance curves in micro siemens, relative to baseline, for the Chill Group ($n = 10$; higher curve) and No Chill Group ($n = 11$; lower curve) (*skin conductance*). Mean heart rate curve of all participants in beats per minute ($n = 27$) (*average heart rate*); time reference axis in seconds. Bars indicating the number of participants (total of $n = 16$) that experienced a chill during the designated phrases, 1–11 (Chills); and *volume* curve of the music in decibels. Note that the length of the music score does not coincide with the length of the played musical excerpt. Also, piano, cello, and double bass parts are alike, and therefore notated in one system for space reasons.

7.3.8 Music and the neurochemistry of social attractions and 'addictions'

The seduction of music, that musical experiences have a knack of being unforgettable, might lead us to wonder whether music can stimulate the neurochemistries of memories and emotions which have evident adaptive value. There is increasing evidence that this is so. Social-bonding in animals is controlled partly by feelings of separation distress regulated by brain opioids, an affective state that may promote addictive urges (Panksepp 1981). Similar brain dynamics have been affirmed in humans with the demonstration that human sadness is accompanied by opioid activity outside the neocortex (Zubieta *et al.* 2003). If the emotional appeal of music relies extensively on the activation of important social emotional processes, some of which, such as mother–infant bonding, are addictive (Panksepp 1998a), then music may have comparable addictive features that may be beneficial, or even essential, to a socially bonded life.

In addition to opioids, infant–mother bonding has strong oxytocinergic components (Panksepp 1998a), and it is increasingly clear that adult attractions are promoted by similar brain chemistries (Insel and Young 2001), leading to their comparison with the addictive aspects of brain seeking desires (Alcaro *et al.* 2007), urges mediated by dopamine (Insel 2003). Both pharmacological and brain imaging studies indicate that brain opioid and dopamine systems participate in peak musical experiences (Blood *et al.* 1999; Blood and Zatorre 2001; Goldstein 1980). This is only the glimmer of a complex neurochemical cascade, yet to be detailed. If we take an evolutionary perspective to our musical nature, we are led to the conclusion that the emotional experience of music is ultimately based on the melodious powers of the human voice, first evident in the loving duets of mother and child. Our understanding of this is not demeaned by the recognition that our uniquely human emotional wealth remains grounded on the ancient neurochemistry of our animal passions.

7.3.9 Neurochemistry of affective systems in the animal brain—music for other species?

The evidence supports the idea that hearing music engages innate neurochemical systems that facilitate social processes, but it is difficult to measure activity in the transmitter systems of the human brain, even though neuropharmacological work can sometimes provide indirect information about their activity (Goldstein 1980). Investigators have usually measured peripheral plasma or salivary products, to assess, for example, cortisol (e.g., Kreutz *et al.* 2004; VanderArk and Ely 1992). Unfortunately, such peripheral measures are unlikely to reflect brain transmitter dynamics with fidelity.

Methodological difficulties such as these have led us to expend much effort to determine how music affects the brain and behavior of experimental animals. Initially, we (along with many others) had the naive hope that some common laboratory animals might enjoy our music, or accept it as reward. Neither we nor anyone else, to our knowledge, has obtained compelling evidence that animals like human music. This does not mean that they are not affected by musical stimuli; they certainly can be (Panksepp and Bernatzky 2002; Chikahisa *et al.* 2006, 2007). After we shifted our focus from laboratory rats, whose vocal emotional communications are typically in the ultrasonic range (20–60 kHz) to newborn domestic chicks, who communicate within our own auditory range, strikingly consistent results have been obtained.²

² Regrettably, most of the work is still unpublished, and is only noted in passing in review papers, because such research is presently viewed by influential journals as of fringe significance. For a summary of the findings, see Panksepp and Bernatzky (2002, pp. 147–148).

Just as mothers calm fussy babies by singing to them, we have found that music reduces the separation cries young domestic chicks emit when they are briefly isolated from social companions, and this calming effect is eliminated if animals are induced into a hyperemotional, agitated state with intracerebral kainic acid (Figure 7.6). Since neuropeptides, such as the endogenous opioids oxytocin and prolactin, are very effective in alleviating chicks' separation distress, we might anticipate that the music was activating these endogenous neurochemical mediators in the chick's brains. Unfortunately, the release of such low concentration chemistries of the brain are very difficult to measure. However, one of the peptides, oxytocin, placed directly in the brain produces the same fixed-action patterns in young birds as does music. When we administer oxytocin, or the avian equivalent vasotocin, directly into the ventricular system (since neuropeptides do not readily cross the blood–brain barrier), young chicks show dramatic elevations of relaxed behaviours—yawning, head-flicking, feather-ruffling and wing-flapping (Panksepp 1992); these effects are also commonly observed during the exposure of the birds to music (Panksepp and Bernatzky 2002).

That endogenous opioids, oxytocin and prolactin are presently the most powerful neuropeptides to reduce separation distress (Panksepp 1998a), and are important for establishing social bonds (Carter 1998; Insel 1997; Nelson and Panksepp 1998), suggests that music experienced as calming and seductive may also release these chemicals in the human brain. We wonder whether the elevated levels of feather-ruffling evoked by oxytocin in chicks (as well as the 'wet-dog shakes' in most animals during opioid withdrawal) may have physiological relations to chills evoked by music. These ideas await the development of oxytocin receptor antagonists that can be deployed in human research.

In humans music engages such a range of emotional states that it surely activates a vast symphony of neurochemical changes. In addition to interacting with comfort-regulating neuropeptide systems, music may also interact with generalized arousal and attention systems of wakeful consciousness, such as those based on norepinephrine and serotonin that regulate more environment-focused emotional responses (Panksepp 1986). We evaluated the efficacy of Auditory Integration Training, a music-based treatment for early childhood autism (Rimland and Edelson 1995; Waldhoer *et al.* 1995) to reduce stress in chicks. Major effects were demonstrated on brain norepinephrine attention systems (increased transmitter synthesis), with more modest effects of dopamine and serotonin (for a summary, see Panksepp and Bernatzky 2002, pp. 147–148). This work opens up the further possibility that musical stimulation can modulate the expression of specific genes in the brain, and potentially effect permanent epigenetic changes by regulating the methylation of certain genes. Other emotional states have influenced gene expression profiles (e.g., Kroes *et al.* 2006).

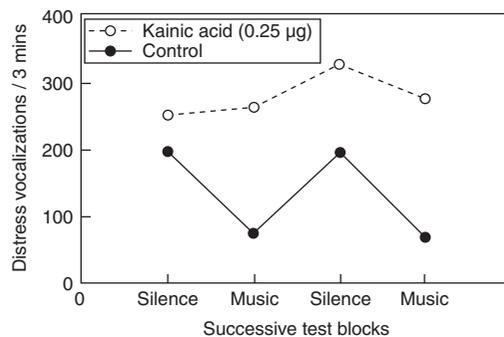


Fig. 7.6 Reduction of distress calls of domestic chicks by music.

Given the clear effects of music on chick affective neurochemistry and behaviour, we inquired whether chicks and rats exhibited any preference for human music. We never did obtain robust evidence for this. To this day, there is insufficient evidence that any other species likes human music. Nevertheless, that music can facilitate human brain dopamine synthesis, reduce blood pressure, and alleviate Parkinsonian symptoms (Bernatzky *et al.* 2004; Sutoo and Akiyama 2004), leads us to wonder whether some aspect of the effects of music on brain regulation might not be usefully studied in animal models, and may even find application in animal care.

In pursuing ideas of cross-species aesthetics, we should not neglect animals' own, species-specific forms of emotional communications and their own rhythms of expression (Hauser 1996). They are likely to find the socio-emotional sounds they produce more attractive than the ones we generate (e.g., Bradbury and Vehrencamp 1998). For instance, the playful 50 kHz chirps of rats, totally inaudible to us, and so abundant during their rough-and-tumble play and sexual solicitation (especially during playful tickling by skilled humans) may resemble the laughter which expresses shared excitement, relief and joy in apes and humans (Hooff 1989; Panksepp 2005c, 2007a). These laughing sounds serve as social attractants for young rats (Burgdorf *et al.* 2007; Panksepp and Burgdorf 2003). By amplifying and stylizing such acoustic signals as are emotionally relevant for other species, we might increase preferences above and beyond the animals' attractions to natural calls. If so, perhaps we could create simple socially attractive messages of 'protomusic' for other species—perhaps by using musically stylized clucking sounds for chickens, squealing/snorting sounds for pigs, meows for cats, 50 kHz chirps for rats, and so forth. Might experience with such protomusic modulate their social tendencies, as does the affective quality of the speech of experienced animal handlers? Might the sound of preferred music make their lives in monotonous laboratory and confined farm situations more pleasant?

Animal models have dramatically advanced our understanding of genetics (Ridley 2003), the mechanisms of learning (Kandel 2006), and the fundamental neurobiological nature of human emotions (Panksepp 1998a). Might they eventually give us a theory of emotional motives for music?

7.4 The applied psychobiology of music

7.4.1 Musical affect and the training of musical intelligence and skill: beyond animal signs to composed art

Human musicality is both innate and powerfully teachable: we make music and share it with children in cultural forms, and children at play create and teach one another their own 'intuitive' musical culture (Bjørkvold 1992). The making of music opens up creative psychological spaces within and between humans that do not, as far as we know, exist in other animals. Perhaps the critical evolutionary novelty in humans relates to the polyrhythmia of bodily expression released by the evolution of bipedal walking—to the *intrinsic motive pulse* of walking, marching, skipping, dancing, waltzing people, with two hands and ten fingers free as complementary messengers of intricate thought and skilled purposefulness (McNeill 1992; Trevarthen 1999). There is evidence from studies of chimpanzee gestures that flexible sign-making by ritualized hand movements may have preceded the evolution of speech, that gestural signing led to making audible signs by mouth that could become symbols (Pollick and de Waal 2007). After all, a sign in music is, in a sense, 'audible gesture', whether made by mouth or with an instrument. But, in addition, some new sense of the extended messages of gesture that can be learned as stories is involved in the genesis of music—what we have been characterizing as its 'narrative power' (Kühl 2007; Imberty and Gratier 2008).

Perhaps the polyrhythmic texture of human musicality grew from the complex new manual skills needed for primate tree-climbing and highly flexible foraging; these are activities in which hand and finger movements move rapidly in well-planned fugues of complementary industry, the two cerebral hemispheres taking different roles in the planning, control and learning of the manipulative skill, and in planning strategies for exploratory or creative activity (Trevarthen 1978, 1995). Musical composition and performance certainly depend on the human urge to discover, create and practice new intricacies of skill for moving by hand and mouth, and for hearing acts that have been accomplished (Donald 2001; Schögler and Trevarthen 2007). There is theory and evidence from functional brain imaging that in hominids the development of new brain systems for coordination between body movement and expressions of hand and mouth were crucial in the evolution of speech and language (MacNeilage 1999; Willems and Hagoort 2007).

Music arises from a distinctly human instinct for cultural inventiveness, of action and thought as art—together making up new and valued creations of mystery and imagination (Dissanayake 1988), building a shared habitus of meanings (Bourdieu 1990; Gratier 2008). All musical inventions, however spontaneous or unpremeditated, tend to adopt, elaborate and remember discrete conventions of execution and composition. Even babies, only 6 months old, want the ritual movements of 'their' baby song to be performed 'correctly', with the 'proper' interpersonal coordination (Trevarthen 2002; Merker Chapter 4, Eckerdal and Merker Chapter 11, Gratier and Apter-Danon Chapter 14, this volume).

Conventional musical tones (i.e., notes) are artefacts of a musical tradition, derived indirectly from natural emotional sounds (Brandt, Chapter 3, this volume). Musical notation is, of course, a rational tool, developed to fabricate and communicate musical forms on paper. In reality, none of the musical notes, as played by a trained score-reading musician, will be just the 'pure' sounds as represented on the printed page. All varieties of emotional animal sounds, and all human vocalizations, including those of singing, as well as the sounds of an expressive instrumental performance, are modulated, with fluctuations of intensity and timbre; these modulations are essential to the expressiveness of such sounds (Lee and Schögler, Chapter 6, this volume).

As a cultural medium, music derives additional satisfactions from cognitive processes and rational transformations. Musicians gain command of their creations by learning the conventional elements, and by discovering the skill of modulating tonal identities to blend emotions in exciting ways (Brandt, Chapter 3, this volume). However, while we are a species motivated to invent artificial meanings that become the arts, techniques, rituals and languages of our shared world, we never lose the taste for spontaneously expressed emotions, such as may occur in the heat of the moment during a performance by a highly skilled musician, or during a rollicking play song sung by a mother to her infant. The 'dynamics' and 'harmonies' of these emotions powerfully affect the quality of our relating.

7.4.2 The aesthetic foundations of musical performance

How we perform music with skill or compose it with intelligence, and how we are moved by music, entails different neuropsychological abilities, cognitions and skills, but both creation and enjoyment share affective foundations. Our immediate experiences of emotions prepare for cognitive elaborations, such as those reinforced by cultural conventions that are essential for the full appreciation of musical art (Merker Chapter 4, Turner and Ioannides Chapter 8, this volume).

Skilled musicality has, as well as complexity, the special neurally mediated quality of *beauty*, telling a memorable story with the the aesthetic appeal of a graceful presentation. When charged

with communicative significance the grace of moving becomes highly emotive, both personally and interpersonally. Beauty is valued because it can be shared. It makes human works and natural objects 'special' (Dissanayake 1988).

Art is concerned with the direct communication of the pleasure of creating shareable experiences and objects. It enhances rituals and 'stories' of performance without regard for practical products; that is what distinguishes it from 'technique'. However, the skills of advanced artistic performance combine art and technique (Flohr and Trevarthen, 2007; Rodrigues *et al.* Chapter 27, this volume), and learning such skills changes parts of the brain that store elaborated representations of action and experience in the massively adaptable tissues of the cerebellum and cerebral neocortex (Schlaug *et al.* 2005). Learning musical perceptual or executive knowledge and skills must involve systems of the brain at all levels, and not all of these can be called 'emotional', although all may be subject to emotional evaluative influences (Molnar-Szakacs and Overy 2006).

Playful arts and rituals most probably have special value for development of the child's brain and of skills that are valued in healthy societies (d'Aquili and Laughlin 1979). Early education in active, enjoyable musical experience, with opportunities to acquire and share fluent emotive expressions of musicality, may have profound positive consequences for the rest of a child's mental apparatus and for overall development (Bjørkvold 1992; Custodero 2005; Flohr and Trevarthen 2007). Such enjoyable activities may activate neuronal growth factors within the brain, and also epigenetically invigorate brain systems that promote life-long satisfaction with being alive, thereby diminishing depression. The role of arts in early childhood education has diminished markedly, especially in the United States, as 'no child left behind' politics of 'back to basics' has trumped emotional engagements with the arts (though see Fröhlich, Chapter 22, this volume, for an exception). To delete music and the arts from the school curricula with instruction limited to rational and technical skills, may be tantamount to leaving every child behind—a false and insensitive economy (Rodrigues *et al.* Chapter 27, this volume).

7.4.3 The emotional effects of music in the regulation of mood, movement, and thought

Music is highly effective for mood induction (Camp *et al.* 1989; Kenealy 1988; Mayer *et al.* 1995; Stratton and Zalanowski 1991), and more robust effects are achieved when one uses participant-selected rather than experimenter-selected music (Carter *et al.* 1995; Thaut and Davis 1993). When formally evaluated, the mood changes induced outlast the music by only about 10 minutes (Panksepp and Bernatzky 2002). This is about as long as the Mozart Effect on spatial reasoning tasks (Rauscher and Shaw 1998), supporting the conclusion that both effects are mediated simply by non-specific attention-focusing arousal effects of music. Newborn infants may be calmed by music, especially if they show signs of actively listening to it (Standley 1998). Parenthetically, calming effects beneficial to learning have also been seen in laboratory rats (Chikahisa *et al.* 2006, 2007). Changing affective dynamics and the stimulation of 'generalised amodal cognition' (Kühl 2007) may underlie the widely heralded Mozart Effect (see Crnec *et al.* 2006, for an overview of the literature on the cognitive and academic effects of music listening in children).

Positive moods evoked by music can facilitate creative output (Adaman and Blaney 1995), but there are difficult measurement issues to be resolved (Asmus 1985). It is less doubtful that the pleasures derived from having one's creative musicality applauded by others as fascinating and beautiful is a very powerful reinforcer of emotions of pleasure and well-being displayed in

participation with music from early childhood (Bjørkvold 1992; Trevarthen 2002; Custodero 2005; Mazokopaki and Kugiumutzakis, Chapter 9, this volume).

The impact of music on the control of bodily movement is both immediate and profound, and young children spontaneously move to music without instruction (Bjørkvold 1992; Scott and Panksepp 2003b; see Lee and Schögler Chapter 6, Mazokopaki and Kugiumutzakis Chapter 9, Fröhlich Chapter 22, and Custodero Chapter 23, this volume). An ancestral relationship between emotions, distinct types of action tendencies, and the sounds we make is ancient and fundamental to our nature (Todd 1985). These relations are instantiated in the creative power and affective immediacy of dance as well as music. Much ancestral knowledge of our species was traditionally transmitted through ritualized chanting and dance, which can represent, in captivating metaphorical ways, how ritualized sequences of complex culturally important actions should be conducted (Turner 1974, 1982; Lakoff and Johnson 1980; Donald 2001; Mithen 2005; Cross 2007; and Brandt Chapter 3, Merker Chapter 4, Cross and Morley Chapter 5, this volume).

The ability of rhythmic music to promote and coordinate powerful bodily actions has surely served as an impetus for the biological-cultural coevolution of music and dance. In many cultures no semantic distinction is made between music and dance. For instance in the Igbo language *nkwa* denotes dancing, singing and playing instruments. There is no concept of a music solely of sound (Cross 2001; Cross and Morley, Chapter 5, this volume). The same was true for the word *musikè* (μουσική) in ancient Greek, which signified music, poetry and dance (Storr 1992), all celebrated in the Dionysian rites.

Endless varieties of self-regulating and self-expressive movements are added by arms and hands, which also aid the regulation and transmission of thoughts and concepts as they gesture in intricate coordination with eyes, facial movements and the intonations of the voice (Nespoulous *et al.* 1986; Varela *et al.* 1991; McNeill 1992; Goldin-Meadow and McNeill 1999; Gallese and Lakoff 2005).

Disorders of communication due to rhythmic body movement, as in the dopamine deficits of Parkinson's disease, can be partly alleviated with music. Symptomatic relief of motor difficulties, including involuntary movements that disrupt expressive gestures, have been noted during exposure to the insistent rhythms of music (Sacks 1973). Clinical reports have been affirmed with more rigorous approaches (Bernatzky *et al.* 2004; Pacchetti *et al.* 1998; Lee and Schögler, Chapter 6, this volume). Indeed, physical exercise and music can promote the synthesis of dopamine in animal brains (Sutoo and Akiyama 2003, 2004). The therapeutic use of musical activities to promote relief from effects of severe trauma result in improved motor control as well as emotional and social benefits bringing self-confidence and joy (Robarts Chapter 17, Osborne Chapter 25, this volume).

7.5 Conclusion: affective regulations in the syntax and semantics of music and language

The importance of musicality for education brings us back to the question of the relationship between communicative musicality and language, and the brain systems involved. Infant studies show that musical communication exists between human infants and their mother before the emergence of propositional speech (Trehub 2006). With maturation, the diverse emotional-musical communications of the infant separate into two streams—propositional speech flows toward the left hemisphere, while the prosodic-emotional stream flows more forcefully into the right hemisphere (Callan *et al.* 2006; Turner and Ioannides, Chapter 8, this volume).

If we dissect this argument into component parts, a case emerges for the evolutionary source of motives for human language as indicated in the emotional sounds of other species, that led to the pre-human emergence of a form of shared meaning comparable with the communicative musicality of infancy. This can be summarized as follows:

- 1 Animals communicate with emotional sounds, and with greater subtlety than usually imagined (Burgdorf and Panksepp 2006; Panksepp and Burgdorf 2003), but only affectively (Panksepp 1998a, b; Wallin, Merker and Brown 2000, Section II; Fitch 2006).
- 2 Music is the ‘language’ of emotions, and its affective power arises from subcortical emotional systems (Blood and Zatorre 2001; Menon and Levitin 2005; Panksepp and Bernatzky 2002).
- 3 A protomusical competence, coupling manual gestures with vocal gestures in narrations leading to protolanguage (Halliday 1975) precedes language in development of the human mind (Fernald 1992a, b; Trehub *et al.* 1984; Malloch 1999; Trevarthen 1999).
- 4 Communication by musical vocal gestures and vocal and manual language capacities remain tightly coupled and they engage overlapping processes in the brain (Callan *et al.* 2006; Schwartz *et al.* 2003; Turner and Ioannides, Chapter 8, this volume).

It is clear that the prosodic aspects of vocal expression are not only supremely important in leading the infant into comprehension and production of speech, but in language learning throughout life (Fonagy 2001). The same rhythmic phrases and affective tones, melodies and prosody, of intentional activity are shared in music and language from their earliest stages through the most complex elaborations. The brain that learns language is an organ of intersubjective collaboration, and to this end has systems of emotional regulation that are fundamentally musical.

Thus, it is reasonable to envision that human language differentiated from our initial affective–musical motivations guiding emerging cognitive abilities. Our provisional conclusion, like those of others who have thought outside the box of ‘the language instinct’, is that not only did our inborn musical nature derive from our more ancient socio-emotional nature (Panksepp 1998b, 2005a), but the emergence of language was preconditioned by our capacity for emotional feelings (Shanahan 2007). Vocal affective communication may have been a precondition for the evolution of propositional communication by speech.

7.5.1 Coda: the immediate future of bio-musical research

The relationship between social processes and our enchantment with music, as emphasized throughout this chapter and this volume, informs us about the nature and importance of shared emotions. Music can amplify our sense of our unique place in animal nature—our capacity to appreciate the profound joy, sadness, power and wonder of this life and its moral complexity. It can become a critical ingredient in our sense of power and our triumphant feelings of victory, or our sense of compassion and responsibility toward those who suffer. Music amplifies our awe at the vast beauty of our physical, social and mental universes. Thereby it readily becomes a natural part of religious tradition that may also rely deeply on the biology of social bonds (Ostow 2007).

One day, when our still ruthlessly reductionistic neuroscientific culture begins to recognize and accept that our souls are profoundly biological (Panksepp 1998b), we will truly understand how music touches and transports the human spirit. Then we will begin to understand how music, while it also easily captures pounding erotic rhythms and patriotic fury, can enrich our capacity for gentle communion and forgiveness—our search for solace and grace. The evolutionary roots of all our musicality are deeply embedded in the evolved passionate nature of our minds, all of

which is grounded in complex bodily representations which we have here encapsulated in terms such as the core SELF with central SEEKING urges transported through Intrinsic Motive Formations. We will have to find ways to study the large-scale neurodynamic rhythms of the living brain to gain a deeper understanding of how the emotions that move us are elaborated by such neural networks (Panksepp 2000b).

Our love of music ultimately reflects the ancestral ability of our mammalian brain to transmit and receive sounds of emotion in movement—sounds that can arouse affective feelings that are implicit indicators of adaptive vitality. Many emotional calls and cries we make were evolutionarily designed to communicate whether certain actions or events were likely to promote or hinder our well-being and survival. Among brain areas long implicated in the evolutionary generation of expressions of emotionality in animal brains (Panksepp 1998a, 2005a), modern brain imaging has revealed dramatic and deep subcortical foundations for peak musical experiences (Blood and Zatorre 2001; Menon and Levitin 2005). An understanding of how music arouses the emotional/affective processes of the brain will eventually provide a scientific understanding of how we come to love music, and what benefits—perhaps the vitality of language itself—we gain from such loving attachments and affective relationships with sound.

The role of subcortical emotional systems in our love affair with music remains greatly underestimated, as it has in consciousness studies until recently (Panksepp 1998b, 2005a, b; Denton 2006; Merker 2006). Without the intrinsic ancestral dynamics of emotional systems, learned musical facility remains affectively flat, its intricacies becoming only an intellectual exercise or a muscular tour de force.

Upon such fundamental emotional foundations artists can construct simple melodies we will never forget, or magnificent sonic spaces, to fill cathedrals or concert halls or outdoor rock festivals. They have created cultural musical traditions reaching far beyond simple affective or evolutionary concerns (Becker 2004). Musical meaning is eventually embedded in these cultural creations and the neuro-affective structures of our minds. Any attempt to understand music in either evolutionary or neurophysiological terms will, of course, be reductive approximations and fall short of explaining the wealth of musical sound constructed in the diverse sociocultural dimensions of aesthetics. If we are to establish a basic psychobiological knowledge for this difficult field, we must be content, first, with provisional simplifications of the natural complexities. Through successive empirically guided theoretical approximations, we may generate some lasting understanding of the mental apparatus by which our passions, intelligence and skill are coordinated into the artistic whole.

Experience and education massively expand these potentials, awakening an appetite for endless cultural inventions. In this way music moves us on, in a world of shared meanings of many kinds.

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