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Essay

Music Listening as Kangaroo Mother Care: From Skin-to-Skin Contact to Being Touched by the Music

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Abstract: The metaphor of being touched by music is widespread and almost universal. The tactile experience, moreover, has received growing interest in recent years. There is, however, a need to go beyond a mere metaphorical use of the term, by positioning the tactile experience within the broader frame of embodied cognition and the experiential turn in cognitive science. This article explores the possible contribution of a science of touch by defining music as a vibrational phenomenon that affects the body and the senses. It takes as a starting point the clinical findings on the psychological and physiological value of tender touch with a special focus on the method of kangaroo mother care, which is a method for holding the baby against the chest of the mother, skin-to-skin. It is seen as one of the most basic affiliative bondings with stimuli that elicit reward. Via an extensive review of the research literature, it is questioned as to what extent this rationale can be translated to the realm of music. There are, in fact, many analogies, but a comprehensive theoretical framework is still lacking. This article aims at providing at least some preparatory groundwork to fuel more theorizing about listening and its relation to the sense of touch.

Keywords: musical haptics; vibrotactile music; touch; coping; kangaroo care; reward system; musical enjoyment; chills and thrills

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1. Introduction

Music is not merely a collection of sounds. As an evolved kind of transferable vibrational energy, it can cut right to the bone, not only in a metaphorical sense but even in a physical way. This is obvious in the case of attending a real-time performance of music, but even listening to pre-recorded music can sometimes provoke an overwhelming experience. Obviously, not all music has the same evocative power, and some typical genres, such as opera arias or lyrical songs, may have a preferential state in this regard, especially when performed by specific performers. There is, for example, an abundance of music recordings on the internet with "highlights" or "bests of" by famous singers, even with historical performances of performers who already died years ago. Take the example of some Puccini areas from Manon Lescaut ("Sola perduta abbandonata" sung by Virginia Zeani or "Fra le tue braccia, amore" sung by Maria Callas") and see the reactions of visitors on the web, with comments such as hair-raising, full-bodied singing and psychological portrayal. Even if the sound quality of these recordings does not meet the current standards of sound reproduction, they can still trigger a cascade of physiological reactions—commonly described as chills and thrills—on the condition that the listener manifests the needed openness and receptivity to respond almost viscerally to the music.

The picture that pops up here is the metaphor of being "moved" or "touched" by the music, which can be taken literally or figuratively. This paper argues for both, by delving into the relation between music and touch. By conceiving of music as a vibrational phenomenon with great penetrating power, it argues for a reconceptualization of it in terms of tender touch, starting from the analogy with skin-to-skin contact on babies, as studied in the clinical setting of kangaroo mother care therapy. A central question is whether music can have an effect equivalent or similar to skin-to-skin contact on babies. Neurological, physiological, and psychological approaches from an extensive literature review are used to support this claim.

1.1. Music Has Penetrating Power

Music has penetrating power. It can be very intrusive and invading and may be experienced as spanning a continuum between acoustic rape—in the case of extremely loud music—and subtler sensual touch. As such, it is possible to conceive of music listening in terms of a sexual encounter, with this caveat that the whole experience should be "deseroticized" to some extent, as music acts as a virtual agent only, and not as living participant in a real bodily exchange. The analogy with a mom who cuddles her baby is quite illuminating here. It is a kind of behavior that develops and nurtures the parent–child bond, and no one will consider such contact as having sexual connotations, though there is a large overlap between the actions and experiences that characterize both kinds of contact. In what follows, we elaborate on this analogy, equating to some extent the music with the cuddling mother and the listener with the cuddled baby. The idea is quite novel and potentially insightful, but its application to either music research or music learning is still tentative and waiting for empirical support. It makes sense, therefore, to examine how music and touch go together, by providing some preparatory groundwork to fuel more theorizing about listening and its relation to the sense of touch. Much is to be expected here from the neurochemical and neurophysiological responses to the music as an eliciting stimulus, the neurobiology of bonding behavior, and the neuropharmacology of social cognition and affiliative behavior. The starting point, however, is music's vibrational energy, as well as the way it is received by the listener.

Music, as vibrational energy, thus impinges on the listener, either in a consensual or forced way. It can literally penetrate the body—it has "penetrating power"—and this potential to influence listeners at a very basic physiological level is comparable to the possibility of touch to directly invade in the so-called "bubble of privacy" that people maintain around themselves [1]. The penetrating power of music, moreover, has been applied even in the use of sonic weapons with the aim to dominate and confuse targets or to destroy prisoner's subjectivity in the interrogation room. Yet, this same intruding power is sought after by some listeners in their tendency to listen to extremely loud music merely for pleasure [2]. Listening, in that case, has been described by Cusick as "a shared experience of being touched-without-being-touched by the vibrating air" from which she drew "a deeply sensual, erotic (though not explicitly sexual) feeling of communion with the friends and strangers around [her]" [3] (p.6). She typically describes how strongly listeners may experience the music they listen to, but even with less intruding ways of listening, music can be experienced in terms of (quasi-)tactile stimulation. This intrusion, therefore, can also be perceived as beneficial, provided that it is wanted and enjoyed. Care should be taken, however, not to overestimate this so-called beneficial effect as social norms and learned effects may bias the listener's subjective appraisal of the music (see [4] for an overview). Sociological studies on the effect of background music in public spaces, such as restaurants, cafés, bars, and stores, have revealed that the claimed benefits of (often too loud) background music are not corroborated by common customers, with a significant number of them seeking places without background music, while simultaneously complaining about their lack of control over the music that is played [5].

Music, further, engages not only the sense of hearing, but it also impacts the sense of touch [6] and the vestibular system in the inner ear [7–9]. This means that the experience of music involves the combined activation of several sensory modalities, which makes it such a rich and touching experience. Vibrations—being the starting point of each musical experience—impinge directly on the skin, which is the largest sense organ of the body. They can be considered primarily as exteroceptive sensations, as long as the contact is limited to the skin. The same sensations, however, become proprioceptive if the vibration extends deeply to the viscera and deep tissues of the body [10], challenging to some extent Sherrington's classic tripartition between exteroception, interoception, and proprioception with sensations that act upon the external surface of the integument (exteroception); the internal surface of an organism (interoception); and the receptors that provide information about the condition of deep tissues, the organism's activity, its movements, and effects of displacement in space (proprioception) [11]. It makes sense, therefore, to consider the whole somatosensory system. It shares with the vestibular system the overarching purpose of informing the brain about the mechanical state of the body that it inhabits. In contrast to the vestibular system, which operates in the rather low-dimensional space of translations and rotations of the head, the somatosensory system has as its input almost the whole body [12], with information from connective tissues (tendons and ligaments), the muscles, and the skin. These are an essentially deformable structure that relates to an infinite domain and that depends on the changes of the internal mechanical state of the body to infer the properties of the objects that are being touched.

This broader approach to sensory modalities is challenging (see [13]. It opens up new avenues to welcome a "multisensorial approach" that can be mild or overwhelming. It also clearly demonstrates that music can be felt as a dynamic and living experience, which is different from detached and disembodied ways of dealing with the sounds, as exemplified in purely verbal statements about music [14]. Listeners, in that view, do not experience the music as an external, knowable object—something out there—but as a dynamic, multifaceted, and multisensorial phenomenon that arises through complex interactions of their physiological functions with the sounds [15]. The effects can be described accordingly as "devastating, physically brutal, mysterious, erotic, moving, boring, pleasing, enervating, or uncomfortable, generally embarrassing, subjective, and resistant to the gnostic" [16] (p. 514). Music, in that broadened view, is considered as an informationally rich or thick event that goes beyond the constraints of conceptual categories such as pitches, melody, rhythm, harmony, instrumental timbres, and musical forms. It is, in sum, "experienced" rather than "reasoned" or "interpreted" [17–19]. Or to use Jankélévitch's terms, the musical experience is "drastic" rather than "gnostic" [20].

1.2. Celebrating the Sense of Touch

The metaphor of being touched by music is widespread and almost universal, but touch, especially when it applies to human beings, is still somewhat tabooed in empirical research. There have been fascinating perspectives on the role of tactility in general and in the arts in particular (see [21] for an overview), as well as several attempts to provide specific issues about tactile culture [22–24]. Theorizing about the sense of touch has been taken up also by several French philosophers in the 20th century [25,26], but as a whole, the tactile culture has remained somewhat under the radar in the academic world. This is now gradually changing with a cautious reappraisal of the sense of touch, as exemplified in the tactile turn in aesthetics. This tactile approach, though long neglected in academic circles, has ended up getting some attention in clinical settings, with caregivers and clinicians starting to recognize the psychological and physiological value of tender touch. Affectionate tactile stimulation, however, has still a long history of discard in the process of child raising—it should make children weak—but this has changed drastically since the seminal work by Montagu in the 1970s who redefined affectionate touch as a basic requirement for a healthy, happy, well-socialized life [27,28].

Besides this affectionate touch, with its potential developmental implications, there is another field that celebrates also the tactile dimension, namely, the whole domain of *musical haptics* [29]. It is an emerging field that examines the tactile aspects of music performance and perception with a major focus on the role of haptic feedback in human–instrument interaction and human–computer interaction [30]. The field brings together diverse disciplines such as engineering, human–computer interaction, applied psychology, music perception, and music performance. The latter, in particular, can be considered as a complex system of sensorimotor interactions between musicians and their instruments, which together present a coherent framework to study basic psychophysical, perceptual, and biomechanical aspects of touch, which may be helpful in the design for haptic musical interfaces.

A starting point for musical haptics is the finding that sound and touch are naturally linked, with vibrations being the auditory manifestations of sound. This means that we listen to music not only with the ears but with the whole body, or stated in other terms, there is a relationship between the audio-induced vibrations on the body and the musical experience of both active and passive encounters with the music [31]. A central topic in this regard is the role of *haptic feedback*, which is obvious in the case of playing an acoustic musical instrument. This is the domain of "musical haptics" with its focus on active touch [32,33], auditory-tactile experience [34], and haptic cues [35]. These have found also multiple applications in the domains of gaming, healthcare, virtual reality, and music, with the aim to enhance the overall listening experience by providing an extra layer of sensory information to create more immersive and accessible experiences [36]. The case of musical instruments, however, is quite illuminating as the haptic cues that instruments provide to playing musicians—forces and vibrations exerted on the skin—are the result of direct physical contact with the instrument [34]. The tactile and kinaesthetic feedback from the resonating parts of the instrument provide the performer with relevant information about the performer–instrument interactions where the sensory feedback from the instrument functions as a response to the playing action [33]. The latter is shaped by listening to the produced sounds but also by feeling the cutaneous vibrations and reactive forces—vibrotactile vibration and proprioceptive sensation—that result from the sound-producing actions [35].

1.3. Kangaroo Mother Care Therapy

Touch, in general, has many faces. It is a powerful tool in the interactions between human beings, with conspicuous potential for aggression, sex, and physical coercion. It ranges from the brutality of a physical blow to the most sensual cress, but quite in general it can be considered as a kind of tactile communication and contact, which, due to the directness of its impact, expresses more profoundly and instantly what language can only confer at length. This is exemplified, most typically, in mother–child interactions with preverbal children. Mother touch, which is complementary mother language [37], therefore, has become an issue in healthcare in general and in childcare in particular, with newborns as the preferential subjects of study [38]. This is exemplified in the neonatal context of preterm infants with evidence-based beneficial effects of what has recently been coined as *kangaroo mother care* (KMC for short). Being defined as a method for holding the baby against the chest of the mother—by analogy with the way kangaroos hold their babies in their pouch—the technique involves skin-to-skin contact, chest-to-chest on the parent's bare chest, with the baby in an upright position, wearing only a diaper [39]. It is a non-invasive, supportive, and natural early intervention for preterm infants that allows babies with limited closeness in the clinical setting of the neonatal intensive care unit—the baby is put in an incubator—to benefit from additional threads of sensory stimulation provided by the mother. These stimuli are not restricted to one sensory modality, but they include tactile, olfactory, auditory, thermal, and proprioceptive stimulation as well [40].

Kangaroo mother care was described for the first time in Colombia as an alternative care for infants with low birth weight. It was intended to compensate for the negative effects of the physical separation of the mother from the infant and to provide the physiological stability, the neurobehavioral organization, the feeding success, and socio-emotional benefits of close physical contact [41]. There are, in fact, "hidden biobehavioral regulators"—such as changes in autonomic, thermal, hormonal, and behavioral systems—which are typically not observable, but which become manifest in case of physical separation of the mother from the child [42]. This phenomenon, in its more pronounced form, is known as *separation distress* or *separation anxiety*. It reflects a basic neurobehavioral anxiety system that acts as a trigger to restore the distress of social isolation, rejection, and psychic pain via reintegration into a social group [43,44].

Early skin-to-skin care, provided by the parent's body, is considered the most prototypic affiliative bonding with specific stimuli that activate reward in both the mother and the infant [45]. Tactile stimulation, in particular, seems to work quite effectively by activating affiliative reward processes through the release of sociosexually related hormones. Gentle and pleasant touch, as in caresses and skin-to-skin contact between individuals, is transmitted by slow-conducting unmyelinated tactile afferent nerves (C-afferent nerves) to the insular cortex, which is a paralimbic region that integrates several sensory modalities to characterize the emotional nature of sensory input [43]. Skin-to-skin care, which uses the parent's body, seems to present the most optimal, appropriate, and physiologically stabilizing environment for the newborn infant. It provides a sensitive and individualized proximal environment to let the baby grow and thrive.

The KMC method has proved to be rather successful thus far and has spread across more developed countries. The rationale behind its success is the assumption that skin-to-skin contact during the first hours after birth facilitates the establishment of a pattern of mutual interaction and coordination between the mother and the baby [46]. The transition from fetal to neonatal life, not only for the pre-term but also for the full-term infant, is a most dramatic and potentially hazardous event. It is characterized by high levels of stress—as exemplified by catecholamine and cortisol secretion—and labile neurobehavioral regulation. Methods have been sought, therefore, to provide postdelivery facilitation of the neurobehavioral self-regulatory responses—embracing neural, behavioral, and state regulation—to improve stabilization and to facilitate adaptation to the outside world [47,48]. Kangaroo care should be seen in this context. It is assumed to intervene in the maturational rate of neurodevelopment at an early stage by affecting the autonomic functions, state regulation, and orienting behavior. Or stated differently, it can help the newborn with self-regulation in the presence of incoming information from the outside world by raising the protective threshold or "stimulus barrier" for potential aversive stimuli [47]. The technique, therefore, seems to facilitate the first phases of transition from the intrauterine to the extrauterine world, by providing a smoother neurologic adaptation after delivery.

Kangaroo mother care should not be reserved for pre-term babies. It can equally well be applied to full-term infants, but in both cases, it should occur as soon as possible with compelling evidence that it supports physiological, behavioral, developmental, and social effects [49,50]. It should also not be restricted to "maternal" contact but should be extended to "fathering" behaviors. It has been found, after all, that paternal contact, such as holding infants closely, can trigger multiple hormonal responses, such as increases in prolactin, vasopressin, and oxytocin levels, as well as a decrease in testosterone values [51].

The ventral, chest-to-chest contact in particular provides pleasing tactile stimulation of tactile afferent nerve fibers, with the release of *oxytocin* as a critical factor [47,52,53]. This is a mammalian neuropeptide, which has an important role in birth and lactation, but which has been found also to function as an oxytocinergic system that plays a major role in the formation of attachment bond and parenting [53,54]. It modulates brain and systemic changes in both the baby and care provider [51,55,56] and triggers the promotion of increased maternal–infant proximity [57].

Kangaroo care, further, can be provided in a pure form, with restriction to mere tactile contact or in combination with music [58], either by allowing the mother to sing alive [59] or by using recordings of her voice, other recorded music [60] or live music [61]. Besides or in addition to the chest-to-chest contact, the mother's voice has proven to be an established method to improve postnatal development. It has beneficial effects on behavioral and systemic outcomes, such as feeding, autonomic stability, cardiorespiratory regulation, and neurobehavioral development [62–68], and it lends empirical support to the universal and cross-cultural use of maternal singing to soothe infants and to engage in early interaction and communication. This kind of vocalization, known more in general as *infant-directed singing*, aims at soothing the child and at building a connection between the caregiver and the infant. It is characterized by the use of a loving tone of voice and positive emotions to enhance emotional closeness and to draw the infants' attention towards the caregiver [69–71].

It can be questioned, finally, how this relates to music listening in general. In what follows, we therefore propose to expand the limited scope of mother–child bonding to the broader domain of musical engagement. There have been already many studies on early mother–infant interactions, with a focus on infant-directed singing and interactions [72–74] and on stress and affect regulation by maternal songs [75,76]. The relation between singing, listening, and tactile stimulation, however, has not yet been explored in depth. There are, in this regard, two possible perspectives: on the positive side, there is the search for beneficial effects of enticing interactions; on the negative side, there is the concern about stress reduction and learning to cope with challenging environments.

As to the former, much is to be expected from research on "entrainment" (see below), which, in its broadest definition, is a process whereby two (rhythmic) processes interact with each other to mutually adjust or lock into a common phase and/or periodicity (see [77,78] on the basis of acoustic, visual, and haptic cues as evidenced, e.g., in synchronized group dancing [79]. The haptic cues, in particular, are linked to kinds of entrainment in which there is a physical coupling between the performers through direct bodily contact or indirectly via some kind of mediation. The cues, which operate through different sensory channels (visual, auditory, haptic), may even seem to mutually reinforce each other as in the case of a tango dance, where the partners must entrain both to the sounding music and to each other. The body contact, in that case, increases the physical coupling between dancers but also the joint reaction to the musical cues. It triggers the capacity for interpersonal coordination in time to create a feeling of moving "as with one body". This is obvious while moving together, but the same feeling can also be felt when uttering sounds or singing together "as with one voice", with the fixed rhythms and pitches acting as coordinative constraints [80] (p. 248). As to the latter, it can be argued that music listening can be conceived in terms of homeostatic regulation [81] by relying on the dispositional toolkit for coping with sounds. It is a position that celebrates the role of real-time experience rather than a disembodied and detached approach without any interaction with the environment.

2. Coping with the Sounds

Conceiving of music in terms of experience has triggered a paradigm shift in recent music/aesthetic research. Inspired by the naturalization of phenomenology, which aims at making the experience amenable to natural scientific inquiry [82], it means basically that a phenomenological description cannot suffice to describe and analyze a lived experience. What is needed, on the contrary, is a biological and adaptive perspective on the experience, with groundings in neuroscience and evolutionary biology. There is, in fact, a long history of cognitive and affective-emotional functions, which are grounded in basic homeostatic regulation, as the driving mechanism for self-regulation (see below), and which challenges a strict distinction between art and non-art [83]. Music, in that view, can be defined as a "sound environment" or "sonic landscape" with acoustic cues, which the listener can perceive as being either beneficial or harmful [84,85]. Listening, then, can be considered a way of sense-making and coping with the sounds.

2.1. Management of Arousal and Seeking Reward

It remains a subject of debate as to whether there is some linear-causal relationship between music as an eliciting factor (acoustic cues) and its possible effects. The current findings are by no means conclusive, as there are so many modulating factors—such as the listener's personality; their learning history, motivation, and psychological set; and the setting of the listening experience—that may intervene in the process of coping with the sounds. Yet, some characteristics of the sounds impinge on the sensory system in a less or more predictable way. Examples are the harmful effects of intruding sound and noise exposure during workplace activities, occupational conditions, and non-work or leisure activities such as listening to loud music, which can modify the listener's psychological and physical state, either temporary or permanently [86–91]. There is, on the other hand, a whole category of sounds, which are labeled as "nature's white noise", that occupy a rather wide frequency spectrum. They include real-world and natural noises that are valued mainly for their relaxing and calming effect. Typical examples are the blowing of the wind; the sound of ocean waves, waterfalls, and mountain rivers; rain in the woods; and many others [92].

The biological mechanisms of sound processing, further, are currently well known. They are evolutionary established stable traits—a kind of dispositional toolkit—at least at the lower level of psychophysical and physiological functioning. The adaptive nature of coping with the sounds—the broader field of musical sense-making—however, is still an emerging field of research, with major contributions from the field of evolutionary biology [93,94]. At the perceptual level, listeners should be able to identify and process acoustic variations in the sonic environment, relying both on innate biological dispositions and processing mechanisms that are the outcome of a learning history. At the behavioral level, there seem to be two major mechanisms for coping with the sounds: the management of *arousal* and the seeking disposition for *reward*.

As to the former, much can be learned from the management of arousal and stress, as studied in the psychobiological model of empirical aesthetics, which defines aesthetic appreciation as a function of perceived arousal [95–97]. It places optimal arousal somewhere between novelty and banality, as exemplified in the inverted U-model of arousal— the Yerkes-Dodson law—that models the relationship between stress and task performance or general responsiveness. Its major claim is that optimal motivation for a task decreases when the difficulty increases and that a peak level of performance is reached at an intermediate level of stress or arousal [98]. Music, in this vein, can be mildly stimulating or wildly challenging depending on whether it invites the listener to cope with familiar or novel and unfamiliar sounds. Enjoying music, then, can be hypothesized to be optimal at intermediate levels of arousal, which makes it feasible to assess music in terms of valence and arousal [99]. It makes sense, therefore, to attune listeners to sonic landscapes that offer stimuli in the optimal zone of excitation—above the threshold of hearing and below the threshold of pain and damage—allowing them to respond adaptively to beneficial stressors and to avoid possible distress that could be prompted by harmful stimuli. This does not mean that there should not be any challenge. There is, in fact, the phenomenon of *eustress*, which represents the pleasant stress of fulfillment together with the avoidance of the harmful consequences of damaging distress [100–102]. As opposed to the distress, which is triggered by harmful stimuli or activities, it values the efforts to cope with environmental stressors as being positive in the knowledge that there are no damaging outcomes that could possibly harm the listener's homeostatic level-setting [103]. It is a phenomenon that is related to the concept of *optimal allostatic load.* Allostasis means literally "stability through change, and the related term allostatic load refers to the accumulation of strain as the result of physiological effects of multiple forms of adversity on organs and tissues, due to an overactive or inefficient management of the evoked stress responses [104]. Such strain may provoke risks of pathology, such as the breakdown of organ systems, compromising the immune response, mild or severe cardiovascular dysfunction and disease, elevated cortisol levels and insulin secretion, accumulation of abdominal fat, loss of bone minerals, decreased neurogenesis, increased neuronal cell death, and associated atrophy in the limbic system [105,106]. Yet, there is also an "optimal" allostatic load, in case of successful adjustment and adaptation to the changing solicitations of the environment. It includes the maintenance of load indicators in normal operating ranges and the release of selected brain opioids—β-endorphins, leucine, methionine enkephalins—that have powerful effects by counteracting negative emotions and favoring positive ones [107,108] peptides from the central nervous system, and oxytocin are important players in this regard [109] (see for an overview).

Without going into details here, it can be stated that our body consists of distinct organ systems— the sensory, musculoskeletal, nervous, cardiovascular, excretory, respiratory, digestive, endocrine, and integumentary systems—that work together to maintain constancy of its "internal milieu" [110]. This is done by continuous efforts to comply with basic homeostatic level setting [111] by responding adaptively to life-endangering situations. Such homeostatic regulation is self-regulating by relying on the dynamic nature of our internal physiology through continuous and ongoing adjustments to the demands from the environment. This mechanism was described already by Selye as the *general adaptation syndrome* [112], which entails multiple interactions with the external environment. These are mostly gauged by our senses, which are our primary warning organs and which act as sentinels for possible danger or harmful stimuli.

The seeking disposition for reward, on the other hand, involves a large, general-purpose system that initiates adaptive expectations about the configuration of the environment and its availability for reward [113]. It relies on the coupling of cortical and subcortical regions—the limbic system and brainstem—with their accompanying modulatory neurotransmitter pathways, which are responsible for dopamine release. The complex neurochemistry of the mesolimbic dopaminergic system is extremely important here. It shows that the seeking disposition for reward may have hedonic properties in itself, even if the intended reward is not achieved. A distinction must be made, in this regard, between tonic dopamine release that aims at maintaining a basic level of seeking disposition, and phasic bursts of release in response to specific cues such as unpredicted reward; novel stimuli; prediction errors; physical, motivational, or affective salience; and shifts in attention, all of which carry the signature of approach behavior [114].

The pursuit of and valuing of beneficial stressors, further, is exemplified by the search for safety and security, which is provided most typically in the context of "nurturing" and "care". This is quite obvious in the neonatal environment, where mothers engage in frequent types of physical contact with their newborns, including all kinds of auditive, haptic, tactile, and even thermoregulatory behavior. There is, as it were, a universal need to provide physical—and also psychological—warmth to the baby by restoring the physical fusion that was abruptly broken after delivery. The tactile sense, in particular, is of primordial importance in this early bond, as affectionate touch from a caregiver plays a primordial role in infant development by affecting its somatosensory, autonomic (stress regulation), and immune systems. Taking place through coupled auditory, tactile, and visual signals, it can be seen also as a critical precursor to more evolved types of communication [115–117].

2.2. Adaptive Coping and Homeostatic Regulation

The concept of coping has a lot of operational power. As a survival mechanism, it has been defined as the "cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person" [118] (p. 141). It is illustrated most easily by describing the way hunters survived in the tropical savannah by being attentive and on guard in an ongoing way to react immediately in case of threatening situations. To do so, they had at their disposition a "biological skin bag" that prepares for fight and flight, and which, even in the changed conditions of our technological society, has remained largely unchanged through the ages.

The threatening and stressful situations, moreover, are not necessarily physical threats. They can be mentally challenging as well, as in the case of a mathematical problem or listening to complex or sophisticated music. Music can even be so challenging that listeners feel unable to make sense of it. The literature on coping, however, has been oriented mainly on the negative aspects of avoidance behavior, with a focus on survival-related behavioral reactions to stimuli that are potentially threatening, such as sudden changes in signal intensity from the environment. Such reactions are evolutionary designed to provide rapid availability of the needed energy in case of acute danger and stress [89]. They are exemplified in typical arousal-inducing defensive responses, such as the acoustic startle reflex, the orienting response, the fight and flight reaction, and also the myogenic vestibular evoked potentials [119–123], all of which belong to the categories of warning or alerting reflexes that prepare the organism to avoid threatening stimuli as much as possible. Their most salient characteristic is the activation of the *hypothalamic–pituitary–adrenal axis* (HPA), which triggers the release of adrenocorticotroic hormone (ACTH) and cortisol concentrations above baseline levels with a heightening of the arousal level in general [124–127]. A distinction should be made, however, between acute shifts in reactive activity as in typical stressful situations, and chronic and cumulative elevations of those physiological processes that take place outside of the basal operating ranges [109].

Coping mechanisms, further, provide a subtle balance between the twin behaviors of avoidance of harmful stimuli and search for positive and rewarding ones. Coping, as applied to music, is not merely a physiological reaction to the sounding stimuli; it also involves a way of sense-making of the surrounding sonic world, with a multiplicity of reactions, which range from overt physical reactions, over affective-emotional reactions, to cognitive and mental operations [128,129]. They entail the possibility of a "mediated" way of coping, which modulates the experience and turns negative estimations into positive ones and vice versa, somewhat analogous to the way human beings exert power over their environment. This echoes the principle of *homeodynamics*, which can be understood as a dynamic version of homeostasis, and which claims that the changes in human behavior are determined by the interactions between humans and their environment [130,131].

The concept of *adaptive listening* is quite promising in this regard. It goes beyond a one-sided negative model of avoidance, somewhat analogous to the definition of health, which has been defined for a long time in terms of the medical model of reducing disease and disability. Recent definitions, however, have broadened the scope to include also to the nature of health and well-being [132]. Adaptive listening, accordingly, should not limit itself to the avoidance of maladaptive patterns of listening—as in an ongoing search for auditory overstimulation—but should be directed also at the pursuit of aesthetic enjoyment, which is potentially interacting with the eudaimonic networks of the brain (see below). It is a way of listening that links pleasure to happiness. Music, then, should not be seen primarily as a possibly harmful stressor, but as an "emotionally competent stimulus", to coin Damasio's term [133], that activates the neuroendocrine responses that are connected to the reward center and to the hedonic hotspots of the brain. The other side of the coin is maladaptive listening, where music is experienced as a possible stressor, even if the listener may experience the evoked stress as enjoyable [134,135]. This holds, in particular, for some kinds of (musical) sounds, which are more arousal-heightening than others, as in the case of rough temporal modulations of sounds (examples are screaming, scratching, or breaking glass) and for music that provides stimuli outside of the range of optimal stimulation, as in the case of extremely loud music. Such sounds may selectively activate the amygdalae, which mediate between the threatening stimuli and the defense reactions of the body [136–138]. But even besides these acoustic descriptors of stressful stimuli, it is possible to conceive of maladaptive listening also in the case that music is listened to only for mood regulation but without real enjoyment, or when no psychological benefits are obtained from listening [139,140]. It means that the search for reward is not the ultimate aim of listening in that case. What is aimed at, instead, is a search for overstimulation and "medium maximization", with a tendency to strive for too much wanting, with the danger of losing sight of the "ends" of utility by focusing instead on the "means" [141,142]. Such maladaptive listening entails the danger of reducing hedonic happiness to mere hedonism, or to the pursuit of pleasure for its own sake, with the possible danger of addictive behavior. Addiction, however, is obviously maladaptive. It can be understood as a pathological usurpation of neural processes that are normally used for reward-related learning and that involve the dopaminergic circuits of the brain [143].

It is thus possible to take a biological perspective on music in terms of adaptive and maladaptive ways of coping with the sounds. It is possible to broaden this biological perspective on coping, as well as to conceive of it also in terms of approach and avoidance. This behavioral dichotomy has yielded a lot of theoretical frameworks and empirical research [144], with an initial focus on the avoidance of harmful stimuli. Recent contributions, however, have seen a shift from avoidance behavior to the search for optimal functioning. It is a view that goes beyond a rather narrow conception of hearing as an acoustic warning system in favor of a conception of coping behavior as optimal navigation in the environment in search of opportunities in the world [97]). Such redefinition includes the search for pleasure and enjoyment in an attempt to go beyond the mere management of physiological responses and to generalize from fundamental sensory pleasure or positive affect to those larger hedonic brain mechanisms that contribute to happiness. It is an approach that fosters a transition from mere hedonic responses to auditory stimuli to the appreciation of a full-fledged aesthetic experience [145,146].

2.3. Immersion, Absorption, and Peak Experiences in Music

The scientific study of the aesthetic experience and the implied experience of beauty is still a controversial topic of research. Much is to be expected here from the emerging field of the *neuroaesthetics of music* with its focus on the musical-aesthetic experience, which has been defined by Brattico and Pearce as "[an experience] in which the individual immerses herself in the music, dedicating her attention to perceptual, cognitive, and affective interpretation based on the formal properties of the perceptual experience" [147] (p. 49). It is an experience that combines the attitudes of aesthetic judgment, aesthetic emotions, and preference, together with some degree of intentionality, affective expectations, and dedicated attention. Its greatest achievement, however, is the broadening of scope from a rather narrow and restricted focus on the "art of beauty" and the "sublime" to embrace the fullness of an aesthetic experience. What is needed, therefore, is a broadening from phenomena that are mostly positively valued—as advocated in the aesthetics of Enlightenment—to span the whole continuum from negative emotions, such as dislike and disgust, to positive ones, such as awe and ecstasy [83]. There is, moreover, a whole list of *aesthetic emotions*, such as wonder, transcendence, tenderness, nostalgia, peacefulness, power, joy, tension, and sadness, as described in the Geneva Emotional Music Scale (GEMS) [148,149], and which differ from so-called utilitarian emotions because they occur in situations that do not by themselves trigger self-interest and goal-directed action. Some of them—such as awe, nostalgia, and enjoyment—have attracted the most substantial research, and aesthetic awe, in particular, seems to figure as a crucial characteristic that sets peak aesthetic experiences apart from everyday casual experiences [150].

Peak experiences in general have been investigated in the context of extreme sports and sensation seeking [151] and can be described as intense psychological states with a high level of happiness and fulfillment [152] (see [153] for an overview). They have been reported also in the realm of music, as reported in Gabrielsson's *Strong Experiences in Music* (SEM), which typically describe a state of flow in which "music completely dominates one's attention and shuts out everything else" [150] (p. 67). This holds primarily for performers, whose actual playing, along with their contact with the audience and fellow players, makes them feel inside the music, being compelled and drawn in [154]. A distinction should be made, however, between arousal-heightening experiences—as in sensation-seeking behavior—and milder forms of heightened experience, such as, e.g., chills and thrills. The increased level of arousal is exemplified typically in listening to extremely loud music, which seems to evoke more basic and amodal mechanisms of perception that go beyond the boundaries between distinct sensory modalities (vision, audition, smell, taste, touch, etc.) and that can be seen as a return to the so-called oceanic feeling or state, as mentioned already by Freud (see [155] for an overview). It can be hypothesized as a desire to be surrounded by a cocoon of sound, as exemplified in the rock and roll threshold of around 96 dB Leq, with its excessive vibrotactile and haptic stimulation, especially in the zone of low-frequency energy [156], and which is considered as a source of pleasure to some [4,123]. The milder forms of heightened experience are most obvious in the case of chills and thrills. The metaphor of being "touched" by the music may be taken almost literally here, in the sense that music does not only stimulate the ears. It impinges also on the skin as the touch-sensitive organ par excellence. The phenomena of goose-bumps and hair-rising (pilo-erection), as well as the more poetic term of skin orgasm [157,158], all point in the direction of a strong coupling of the auditory and tactile sense. It raises the question to what extent music can be considered as a kind of substitution for skin-to-skin contact, which brings us to the guiding question of this paper: can music listening be considered a kind of kangaroo care in some derivative way?

Kangaroo care, however, is not merely about touch. It also provides a feeling of bonding, safety, and security. As such, it also fulfills the needs of *cocooning*, which aims at creating a safe, enclosed bubble to compensate for comfort that is lacking to some extent in the outside world [37]. This can be met typically by maternal bonding, but it can be provided also by other means. Music, or at least some kinds of music, can be seen as an alternative to create a sense of connection with others and/or with the sounds. Such feeling of togetherness is most obvious in case of group performance but also listening together and even in isolation can create a feeling of shared experience, with distinctive levels of absorption and immersion. Both phenomena imply a feeling of connection, though they are not quite the same.

Absorption is a standard phenomenon in musical performance. It seems to be the default mode of performing in case that the music, the circumstances, and the performances are not overly challenging. Musicians, then, are not overly distracted or absent-minded, nor are they unusually and intensely concentrated on their tasks. The result is a feeling of satisfaction, with a sound balance between intention and execution. Besides this standard absorption, there are also more intense forms of absorption, in which case this match may be more challenging [159].

Immersion, on the other hand, is a metaphorical concept. It evokes the physical experience of being submerged in water and it has a psychological equivalent in the feeling of being plunging into the ocean or a swimming pool. Generalizing a little, it evokes a sensation of being surrounded by another reality that enthralls, as it were, all attention and the whole perceptual system [160,161] (p. 150). The term, however, has led to several one-sided definitions, highlighting mainly the perceptual aspect of the immersive experience [162,163]. A typical example is that of Witmer and Singer, who define immersion as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" [163] (p. 227). There is, as such, an experience of being transported to a simulated place, with a high degree of presence, involvement, and engagement, each of them spanning a continuum from a lower-level to a higher-level experience. The immersive experience, moreover, is mostly valued as being pleasurable, somewhat related to the concept of "flow" [164], which has been defined as a state of effortless absorption and narrowed but intensified concentration, balancing between challenges and skills, both being relatively high but neither too difficult nor easy [165–167].

There are, as such, many descriptions of the immersive experience, which are used even interchangeably. Quite in general, it can be defined as a state of engagement that holds our interest through sensory, challenge-based, or imaginative means [168]. It needs the allocation of perceptual resources to experience a shift of attention to focus on an alternative reality, which is characterized by a number of characteristics, such as being mentally absorbed; attending to some source of information to the detriment of others, so as to disregard somewhat the real world; to lose awareness of external events; and to instigate a kind of temporal dissociation [169]. Some of these characteristics have been studied extensively in the context of gaming, virtual environments, films, and music, but as a concept, immersion has been overused so as to diminish its analytical value [160]. Alternative approaches, therefore, have been proposed, mainly in the field of digital games (see [170] for an overview).

Immersion, further, can be subsumed under one of two dimensions that define a lived experience, namely, participation—either passive or active—and connection. The latter ranges from absorption to immersion, with the distinction that in immersion one can become physically or virtually part of the experience itself, while absorption means merely that our attention to an experience is brought to mind [171]. The distinction, however, is not always made. Especially with regard to music, the term absorption has been used broadly to refer to a kind of trance-like state of consciousness that is characterized by a heightened and effortless form of attention, in combination with a reduced generalized orientation to reality; an altered consciousness of time, the body, and the surroundings; and a forgetting of oneself [172–176], somewhat analogous to the above-mentioned description of the state of flow. Apart from this definitional fine-tuning, however, it is possible to conceive of an immersive musical experience as an experience that allows persons to "lose" themselves, either as performer or listener, to break down distinctions between self and others, and to evoke powerful feelings of belonging, cohesion, and shared conceptions of identity [177]. It is seen as an example of a high-intensity musical experience, which makes it distinct from broader categories such as involvement and engagement without setting it apart from other states of consciousness.

3. Musical Enjoyment, Pleasure, and Reward

A high-intensity musical experience has a lot of inductive power with possible effects that can be subsumed under two broad categories: the induced physiological reactions and psychological outcomes. Several approaches have been proposed to uncover the underlying mechanisms, with a tentative distinction between cognitive, affective, and visceral functions, all of which are grounded in our basic homeostatic regulation [81]. These functions revolve around four functional categories: (i) the mechanisms of pleasure and reward, (ii) the twin notions of valence and arousal, (iii) the affect-related consequences of music listening, and (iv) the role of visceral reactions to the sounds [178]. Adaptive listening, as mentioned above, should entail that listeners not only listen to the sounds. They should learn, instead, to read also the conditions of their body, to manage their internal physiological functioning, and to direct their behavior toward conditions that make it possible to thrive. The corresponding evoked emotions should be seen as mediators between bodily physiology and behavior on the one hand, and surviving and flourishing on the other hand, with a rich interplay between bodily changes, affect, and cognition [179]. It is an approach that invites listeners to monitor and self-regulate the state of their body to comply with the narrow limits of operating homeostatic set-points to adjust baseline physiological values to their preferential default values. This holds, among others, for hemodynamic processes (blood pressure, pulse rate), respiratory functions (breathing frequency), body temperature, blood levels (sugar, acidity/alkalinity balance (pH), oxygen and carbon dioxide level, fluid balance), etc. What is needed, in other words, is a balance of internal metabolic processes and outward-directed activities that respond to sensory stimulation against optimum target functioning in the pursuit of a controlled state of the internal milieu [180].

3.1. Aesthetic Responses, Hedonic Pleasure, and Eudaimonic Enjoyment

There are, in this regard, some lower-level reactions that can be explained in terms of biochemical reactions and physiological and neural correlates of listening. They make it possible to naturalize the musical experience and to raise the study of musical enjoyment to the level of an empirical study of pleasure and reward [181–187]. Much is to be expected, here, from the biochemistry of emotions and affect—with a major emphasis on affective bonding [43]—the neurobiology of pleasure, and the neuroendocrinology of musical reward, studied both in a positive sense in case of hedonic happiness, and in a negative sense in case of pathological conditions of lack of pleasure [188,189].

Central in this research is the working of the dopaminergic reward system [190], which is only beginning to be unraveled with some depth [113,191–194]. There is, however, not yet conclusive evidence regarding the neurochemical indicators of reward with many contradictory and even confusing findings. This holds in particular for the role of oxytocin and prolactin, and their complex relation to the release of dopamine [195,196]. The underlying mechanisms are not yet totally clear, with underlying theoretical constructions and empirical findings, which, for the time being, provide even more conflicting results (see [197] for a critical discussion).

A major breakthrough in this regard has been the emergence of the above-mentioned field of *neuroaesthetics,* which tries to explain musical behavior in terms of stimuli, brain functions, and motor responses [145,147,190,198–203]. Care should be taken, however, not to generalize too much as the neural correlates of musical reward are just one layer in the processing of the music. There are, moreover, several topics that are still under discussion, to mention, among others, the exact role of neurotransmitters with a special focus on dopamine in the generation of arousal; the relation between pleasure and aesthetic reactions; the statement that all aesthetic reactions can be reduced to some biological origins; and the distinction between aesthetic pleasure as a core pleasure that has its origins in subcortical areas, as against conscious liking that originates in higher-level cortical structures of the brain [204,205]. A possible answer to these concerns is the distinction between chemical and neural responses at the "proximate stage" of processing, and the cognitive-emotional responses of valuing at a more "distal stage". It is a distinction that echoes Tinbergen's proximate and ultimate stages of explanation [206] (see also [94]), with the former relating to an explanation in mechanistic terms of biochemistry, physiology, and neural correlates, while the latter refers to longer time-scales and ultimate functions of survival. The role of positive emotions in the appraisal of music should be mentioned here, as they may be helpful in broadening the listener's behavioral and cognitive repertoire. They exemplify the core assumptions of the *Broaden-and-Build Theory*, which assigns an evolutionary role to positive emotions by consolidating and expanding human's resources. This entails a broadening of the scope of attention, expanding the existing repertoires of thought and action, increasing the openness to new experiences and improving the readiness to engage in the building of long-term resources. These engagements can span a broad range of physical, psychological, intellectual, and social resources, with resilience and curiosity as the most prominent ones. They can trigger the search for pleasurable and enjoyable experiences [142,207] and they are also typical of the adaptive nature of positive and negative affect [208–210].

Music, in this view, can be seen as a tool for *aesthetic empowerment*. As sonic energy, it affects our biological systems and it has the potential to enhance our mood and motivation through dopaminergic activity within the reward circuit and to modulate the level of physiological arousal through the autonomic nervous system, relying on both the sympathetic and parasympathetic branches [145,211–213]. This is exemplified most typically in the musical-aesthetic experience [147].

The question can be raised as to whether such an experience of aesthetic reactions should be considered as generic strategies for survival, rather than specific reactions to a more constrained subset of the environment. There is a lot of empirical evidence that indicates that brain regions that are involved in the aesthetic experience overlap to some extent with those involved in other kinds of experience, which means that the art-related responses overlap with those that monitor the appraisal of evolutionary important non-art objects. Examples of the latter are the desirability of food and the attractiveness of potential mates [83]. It thus seems that aesthetic processing co-opts neural systems that subserve also more general "adaptive" assessments, which suggests that the underlying neural mechanisms are to some extent non-specific and general. They are linked to domain-general processes such as motivation, attention, and reward, but they must be seen also in their interaction with artwork-derived sensory processes [214].

The adaptive nature of the aesthetic responses, further, opens up an interesting avenue for future research, with a central focus on enjoyment and reward, and in a more ultimate stage, even on happiness and well-being. By studying the hedonic systems of the brain, music listening can then be raised to the standards of a "science of pleasure", with already some extant studies of the brain mechanisms of pleasure in mammalian brains [188,215]. Much is to be expected from this neurobiological approach. The potential contribution of hedonics to happiness, however, is not simple and straightforward. There is, first, a distinction to be made between two major conceptions of happiness, which have their pendants in two schools in hedonic psychology [132,216]. There is, on the one hand, the hedonic school, which defines *hedonic pleasure* as revolving around being relaxed, avoiding problems, and being happy. Its primary orientation is towards the satisfaction of homeostatic needs—such as hunger, sex, and bodily comfort—with a narrow focus on the experience of pleasant feelings and the avoidance of pain [142,144,217,218]. The eudaimonic school, on the other hand, states that *eudaimonic enjoyment* can break through these constraints by aiming toward broader goals that go beyond immediate satisfaction. It argues for the realization of latent potentials and personal growth, or to realize one's "daimon" or true nature, to use Aristotle's term. Typical examples are prosocial behavior, an artistic performance, an outstanding athletic achievement, or a stimulating conversation.

The hedonic approach, in sum, provides an interesting starting point for the identification of eudaimonic signatures of happiness, as well as pathological conditions of lack of pleasure—as in anhedonia or dysphoria—which may function as major obstacles to happiness. They are quite informative for the study of the underlying mechanisms of happiness. Hedonic happiness, furthermore, may function as a contributing but not as a constitutive condition for eudaimonic enjoyment. Four possible combinations of their contributions have been identified thus far: hedonia and eudaimonia occurring together, hedonia without eudaimonia, neither hedonia nor eudaimonia, and eudaimonia without hedonia [216,219,220]. It thus seems that mechanisms, involved in fundamental pleasure, may overlap with those for higher-order pleasures, though this is not necessarily the case. If so, they seem to involve the same hedonic brain systems, which should be set apart from those involved merely in sensation and thought [188]. They seem to contribute to the broader category of well-being, which embraces both aspects [144].

This search for pleasure is a major incentive for music listening. Espousing the centrality of hedonic well-being in the search for a weighted balance between positive and negative affect has become also a major part of affective neuroscience, which is the field that studies the generation and identification of affective reactions in humans and animals. As a science, it is concerned with objective and measurable aspects of behavioral, physiological, and neural reactions, as well as with the more subjective experiences that are associated with conscious affective feelings [188,215]. Of central importance here is the finding that neural activity in the reward center is a key component of both hedonic and eudaimonic listening.

3.2. Being Moved by the Music: Chills and Thrills

Resonating with the music is not merely a physical and physiological phenomenon. There are derived effects that are commonly referred to as the inductive power of music [19] which revolve around evoked emotions and affects, with a whole system of mappings between the music and the listener, who can be seen both as a resonating physical body and as a subjective human being. There is, further, a lot of variability among individual listeners, both in the frequency and specificity of their aesthetic responses, which makes it difficult to generalize about music-induced emotions and affect. Two major categories of responding, however, have been identified thus far: a heightening of the induced arousal and a whole class of subtle reactions that are subsumed under the umbrella term of *chills and thrills*. Both categories have been the subject of interesting empirical studies, which suggest at least some causality in the mapping between the eliciting stimuli (the music) and the induced responses (psychophysiological reactions), which lend themselves to objective measurement and assessment.

The arousal-enhancing effects are related to the definition of music as a vibrational phenomenon. Sound waves, as physical disturbances, can impinge on the body and the brain, and they can have a role in the modulation of the homeostatic balance. In the worst case, they can become a source of allostatic load [4,81] with either acute shifts in physiological reactivity in response to specific stimuli, or chronic and cumulative elevations of level settings that surpass the basal operating ranges, and that may operate even in the absence of the threatening stimuli [109]. This cumulative effect, in case of prolonged strain, can lead to organ breakdown, a reduction of the immune response, an elevated cortisol and insulin secretion, and finally also to disease [221]. The main effects are reflected in biological stress responses that engage the neuroendocrine, autonomic, and immune systems. Together, they put high strains on the mobilization from the hypothalamic–pituitary–adrenal axis (HPA) with a corresponding activation of the sympathetic branch of the sympatho-adrenomedullar system, with a resultant cascade of hormones, such as corticotropin-releasing factor, corticotropin, and cortisol [81,213,222].

Listeners can thus behave as biological beings who rely on their dispositional neural apparatus for coping with the sounds. Listening, however, is not merely reactive. It can be adaptive and goal-directed as well by searching out those stimuli that are valued as worthy and beneficial, and by avoiding those that are considered harmful and annoying. This is the basic mechanism of coping behavior that evaluates the environment in terms of threats and dangers, but also in terms of possible benefits for survival [223].

This brings us to the subtler response category of chills and thrills, which embrace, among others, feelings of sadness, being touched, tenderness, and being moved [149,224–230]. The latter, in particular, plays a major role in the neurochemistry of emotions. Being defined as a predominantly positive emotion, it has been linked to prosocial and social-bonding behaviors [231], and has been studied also in the context of music-evoked affective neuroscience. There is, however, no simple stimulus–response pattern with structural features of the music inducing specific reactions. The way how listeners make sense of music, in fact, is modulated by their musical preferences and learning history rather than relying merely on acoustic triggers [232].

There is, further, also no full agreement on the concept validity of the chills and thrills constructs. A major question is whether they should be considered as unified constructs or as sets of distinct response categories, which depend on the actual experience, the eliciting stimuli, and the individual differences among chill responders. As such, there have been attempts to provide operational definitions with a first distinction between thrills and chills. Thrills, as the broader category, has been linked to novelty or to some new-found insight, with feelings of tension, awe, and sublimity. Chills, as the more restrictive category, have been related to absorption and being moved [233].

Besides these definitional concerns, there are other methodological issues that relate to the measurement and assessment of theses subtle reactions, which blur, as it were, the distinction between objective reactions of the body and the more subjective appraisals and valuations by the listener. Much is to be expected here from the combination of first- and third-person perspectives on musical sense-making, as proposed in in the field of neurophenomenology (see below), and a further extension of this approach by introducing also the second-person perspective

4. Musical Interaction and the Second-Person Perspective

Music listening is a multivariate phenomenon that encompasses biological, psychological, and cultural factors, which, together, shape the overall experience. The musical experience, however, is first of all a "physical experience" that can be defined as an interaction between the physical body of the listener and the vibrations of the sounding music. Even if the music may trigger psychological feelings and conscious valuing, this does not undo the trivial fact that the first level of musical engagement is a sensory experience. This means that, at a primordial level, all our perceptions and engagements with the world are passively motivated by the sensing body. This passivity, however, is not inactivity. It refers, on the contrary, to the fundamental openness to the world, with a body that actively constitutes multiple relationships with its environment [234]. There are, in this regard, two sources of information, namely, the information that derives from the environment through exteroceptive cues, and the information that originates from within the body through interoceptive pathways. The distinction is important as it underlines the possibility of affective regulation through visceral reactions to the sounds. Music listening, in that view, may have an adaptive and evolutionary function in the sense that the human brain has evolved not only to "read" the conditions of the body but also to learn to "respond" accordingly via the machinery of emotions, which have their basis in certain physiological states [138,179].

Music may thus induce subtle physiological effects on the body, with changes in the concentration of biochemicals in the blood, such as endorphins, cortisol, ACTH, interleukin-1, and secretory immunoglobulin A [235]. This means that listeners can rely on two distinct levels of responding: they can attune themselves to the music as an external stimulus, but also to the physiological responses of their body, even if these are not always manifest [81]. It is a conception that overcomes, to some extent, the distinction between the description of music in objective, acoustic terms and the subjective experience and appraisal by the listener.

A lot of effort has already been made to measure the physiological and neurological correlates of music listening, with findings that are quite robust in their objective description of observed effects. The subjective feelings, however, are more reluctant to objective measurement as they can be measured only in an indirect way. An interesting new approach to this subjective/objective dichotomy is the distinction between a third-person and first-person description of consciousness [236–238]. The objective measurements (third person: e.g., his music has these characteristics) can be reduced to behavioral and brain-based measurements, aimed at tracking the graded nature of consciousness, with a distinction between unconscious and conscious processing [239]; the subjective appraisals, on the other hand, entail descriptions that are tailored to individual listeners (first person: e.g., I experience this music as . . .). The combined approach of both perspectives has been implemented already in the field of neurophenomenology, which tries to enrich the theoretical and philosophical perspectives of phenomenology with the more objective tools of neuroscience and experimental psychology [238,240–243]. There is, however, still another perspective, which is still waiting for additional empirical support, namely, the *second-person approach* [159,244]. This holds when we are engaged in mutually responsive interactions and when other persons appear as an immediate "you" rather than as a detached third person or object [245]. It is a kind of direct perception of other minds, without explicit theorizing, imagining, inference or simulation, relying mainly on bodily interaction [246]. This bodily approach, however, is distinct from common conceptions of social cognition in terms of theory of mind, mentalizing, or mindreading, which claim that individuals impute mental states (e.g., beliefs, desires, intentions, goals, experiences, sensations, and emotion states) to themselves and to others (see [247] for an overview).

Listening to music can be described rather easily in terms of a second-person perspective. By defining music primarily as sonic energy, it can be considered in a derived sense as something that emanates vibrations, which makes it plausible to hypostasize the as a virtual agent. Its traveling energy, however, is not virtual; it impacts the whole body—cells, organs, tissues, and more encompassing organ systems [248]—to arouse physiological responses, which may be either positive or negative. These responses have been the subject of multiple studies—oriented primarily oriented to the negative impact—in the domain of vibroacoustic medicine [249]), which examines the effects of vibrational energy that the body immediately senses, and to which it responds way by multiple kinds of psychological and mental connotations. Some of the negative effects have been subsumed under the umbrella term of vibroacoustic disease [250,251], which embraces a whole list of symptoms that were found in people exposed to low-frequency noise with large pressure amplitude as part of their everyday environments [89].

The vibrational responses, however, are not always harmful or annoying. Recent research has even broadened the scope of research by also exploring the role of adaptation to vibrational energy, with a central focus on the concepts of physiological entrainment and resonance [78]. The phenomenon of entrainment, in particular, has received a lot of interest in current research [77,252–254]. It provides an explanatory framework to describe how physiological systems are able to synchronize and resonate with music as an external stimulus. The analogy with someone who is dribbling a bouncing ball is quite illuminating here. Rather than just dropping the ball and letting it bounce free at its own natural frequency, it is possible to externally impose the number of bounces per minute, so as to force the ball to bounce at the imposed rate of the dribbling person. This rate is the driving or forcing frequency that controls the motion of the ball by transforming its free vibrations into forced vibrations. It makes the ball a controlled system; the dribbler, on the other hand, takes the role of a controller who acts as a continuous disturbance or external forcing function that controls the behavior of the ball as a system [248].

It is quite appealing to translate this to the realm of music and to conceive of music as a "controller" and of the listener as a "controlled system". Music, then, is not merely an auditory stimulus, but a kind of oscillator that emanates its sonic energy, and which is captured not only by the ears but also by the sensory systems that are designed for touch and vibration. Such an approach aligns well with a recent broadening of scope that argues for a multisensory approach to music listening, encompassing, beyond the visual, also the tactile, haptic, kinesthetic, and proprioceptive senses, not in isolation, but as an integrated whole. It is a perspective that assigns a major role to the whole body and its sensorium as a whole, as opposed to "single-sense epiphanies", which celebrate one sensory modality above the others, such as looking only instead of moving and touching, or listening without any reliance on the other senses [255]. Rather than discouraging the use of other sensory modalities, the multisensory approach can contribute to a richer and fuller perception by increasing the feeling of a "first-hand experience" of what impinges on the senses. It provides a kind of presentational immediacy, which is an important factor in the experience of witnessing, as a real-time testimony of what happens in a concrete here and now [18].

The combination of first- and second-person perspective, together with the feeling of presence—as something that is actually here—is an important aspect in the establishment of social bonding, especially in one-on-one engagements. Translated to the domain of music, this is obvious in playing or singing together, particularly in dyadic settings but also in the case that several others are involved as in ensemble playing. It is even hypothesized that mere listening can evoke this sense of presence and togetherness by hypostasizing the music as a virtual person. The most apparent example is a mother singing to her baby while holding the baby in her arms, which brings us again to the guiding question of this paper. It entails an interaction that takes place at multiple levels. There is, first, the sounding music, which is produced in real time by the mother and that provides a beautiful combination of third-person (the description of the sounding vocalization), second-person (the mother, the child, and their interactions), and first-person (what the child/the mother experience themselves) approaches. Besides these interpersonal perspectives, there is also a multiplicity of sensory stimulations, including not only the auditory, but also the visual, the haptic, the tactile, and even smell and temperature sensitivity.

It has been shown, moreover, that musical interactions intensify empathic effects, by promoting mutual affiliation and by acting as a kind of social glue [256,257]. This holds in particular for an intimate coupling as mother and child (maternal singing), but it is arguable to extrapolate the beneficial effects also to other interpersonal settings that are not restricted to children and neonates. It is an area of research that has implications for mother–child singing, choir singing, and remedial singing with cognitively impaired patients. Singing together has been found to facilitate social bonding [258–263]. Choir singing, moreover, seems to facilitate the establishment of social bonds, due to phenomena such as shared intention, attention to, and achievement of a collective goal [264–267] but also to the endorphin release that is triggered by synchronous activity [268–270]. This all contributes to an increase in closeness between group members and to feeling more positive towards each other. The sense of a shared achievement in producing a collective good sound, e.g., is a strong marker of successful coordination and synchrony to produce a collective product makes singers feel more integrated in the group.

5. Conclusions and Perspectives

Summarizing and expanding a little, KMC is an intervention that facilitates direct contact between the mother and the child. It is skin-to-skin, but it can be seen also as the ideal way to transmit maternal sounds, and this applies, in particular, to the case of maternal singing [59] (Arnon et al., 2004). KMC and music, moreover, are established, safe, inexpensive methods that are easily implementable. The use of music, however, resulted in different effects for the mother and the child, which brings us to the final question of this paper: Is it possible the hypostasize the music as a *virtual caregiver* and to conceive of the listener as the agent to be cared for? And is it even imaginable to invert the roles, and to conceive of the listener as the caregiver and the music as a virtual person that, like the baby, needs care? This is highly speculative, of course, but as a thought experiment, it opens up new avenues for music education and music therapy in clinical settings. What is needed, in particular, is a theoretical framework that brings together concepts such as immersion, absorption, physical contact, connection, attachment, bonding, empathic listening, pleasure, and reward. It is possible to assess these indicators in the case of mere listening, but it is possible to assess them also in the case of KMC. It is clear from the above-mentioned findings that there is, in fact, a lot of overlap. Much more substantial research is needed, however, to explore this challenging domain, which opens up perspectives for a clinical approach to music listening, with the aim to investigate what happens at the neurobiological and neurochemical level of listening, as well as identifying the underlying mechanisms that can modulate the responses to the music. One of the major challenges, in this regard, is the generalization from how tactile and proprioceptive cues may enable embodied kinds of interactions so as to achieve high levels of performance and expressivity to also enhance the fulness of experience in mere listening situations [32]. This holds in particular for individuals with hearing impairments, who should be enabled to rely on haptic feedback to enjoy music in a new and unique way. There are currently already special devices that have been built to translate some basic elements of music into a resembling synthetic haptic vibration. One of those is the *haptic music player*, which is considered as a sensory substitution system that translates the sensory information from hearing to touch [271,272]. It is a promising development that explores different methods of interactions to better “feel” the sound, with possible benefits for children with profound and multiple learning disabilities. The rationale behind this approach is simple: tactile vibrations are assumed to enhance the music listening experience. It is to be defined, however, to what extent the tactile vibrations should be congruent with the original sound source, and it is still to be discussed which parameters of the tactile vibrations (intensity or frequency of the vibration) should match those of the music [273]. The audio-tactile congruences, in fact, affect the vibrotactile music enhancement, and understanding the audio-tactile congruence framework may be beneficial for the design of wearable, vibrotactile devices for music listening. Common to most of them is a search for audio-tactile intensity congruence and timing alignment [274].

It brings us to the guiding question of this paper: Can music listening be compared to kangaroo care therapy? And if so, what are the benefits of claiming such an uncommon hypothesis? There are, in fact, many analogies, but a comprehensive theoretical framework and more empirical findings are needed to raise the question to the level of a scientific hypothesis. One of the objectives of this paper, therefore, was to provide the needed preparatory groundwork to fuel more in-depth theorizing about listening and its relation to the sense of touch. Several existing theoretical frameworks have been discussed to some extent, such as attachment theory, the neurobiology of bonding behavior, the neuropharmacology of social cognition and affiliative behavior, studies of maternal behavior and sociality, skin-to-skin contact and kangaroo mother care, oxytocin-related neurosecretary processes, hedonic pleasure and eudaimonic enjoyment, and adaptive and maladaptive coping. Moreover, some major empirical findings have been highlighted as well, such as the major role of oxytocin and dopamine release, both in maternal bonding and music listening, with considerable overlap between the oxytocinergic and dopaminergic systems in the brain [193,275].

There is currently substantial evidence from animal behavioral neurobiology (mostly rodents) with regard to the neural organization and neurochemical modulation of behavior-affiliative characteristics of trait affiliation. This mainly reflects neurobehavioral processes that create a subjective emotional experience of warmth and affection, which is elicited by others, and which fosters the development and maintenance of longer-term affective bonds [276]. Affiliative behavior, furthermore, is not gratuitous. It enables physiological adaptations that facilitate so-called trophotropic processes—such as relaxation, calmness, metabolism, digestion, growth, and healing—and it may foster the physiological coregulation of bonding partners [277,278]. It can be argued, therefore, that basic associations can be defined between affiliative stimuli, neurobiology, and neurochemistry [43]. The claims, however, are still tentative to some extent, as many of the findings rely heavily on rodent studies. It is an open question, therefore, to what extent it is possible to generalize from these animals to the primate brain and social life of more-developed animals and humans. It has been found, in this regard, that non-human primate acoustic preferences differ dramatically from those of human listeners, with a major finding that primates do not find mild musical stimuli pleasurable or relaxing, though there is some evidence that they have nontrivial preference for some musical stimuli over others [279]. Much is to be expected, however, from research into the role of neurotransmitters or neuropeptides as u-opiates, as well as the contribution to affiliative reward and bonding of dopamine, oxytocin, vasopression, and gonadal steroids [43].

The challenge, however, is how to translate these findings to the realm of music. There seem to be a number of unexplored paths, which all revolve around the definition of music as a vibrational phenomenon. Music—as transferable vibrational energy—impinges upon the senses, with a major focus on the tactile sense beyond mere auditory stimulation. It is thus possible to conceive in metaphorical terms of being touched by the music. The metaphor, however, can be taken more literally by conceiving music in terms of tactile stimulation. It is an approach that can be positioned within the growing role of embodied approaches to music perception, and which may open new avenues for future research. New paradigms in science, however, do not start from scratch. They often migrate from one discipline to another. Such interdisciplinary fertilization can be symmetrical or asymmetrical, with a mutual (symmetrical) or a unidirectional (asymmetrical) influence of the disciplines on each other, but in both cases, the outcome is mostly a shift in the way of thinking about foundational questions.

The guiding question of this article started from two major claims: (i) kangaroo mother care (KMC)—with its emphasis on skin-to-skin contact—celebrates the sense of touch, and (ii) KMC is helpful in the establishment of social bonding. It is a method to be positioned within the fields of developmental psychology and social neuroscience, making it possible to think about music and the social brain in terms of non-musical paradigms. Starting from the metaphor of being touched by the music, it can then be asked whether music listening can be explained in terms of KMC. The answer is not unequivocal. Music listening, definitely, is not to be "equated" with kangaroo mother care. The underlying rationale behind KMC, however, with its emphasis on tactile stimulation, subjective feelings of safety and proximity, and its corresponding neurochemical and neurophysiological responses, can be applied to some extent also to listening to music. It is a path that leads to an initial understanding of the social neuroscience of music, linking music to neurobiology, human cognition, and social psychology [280]. Music, in that view, is not merely a set of acoustic variables, but a phenomenon that possibly evokes a number of "shared" emotional and/or affiliative experiences, which can facilitate both a sense of "groupishness" and "cohesion" [281]. It is a hypothesis that is grounded in evolutionary claims of music as related to the facilitation of social bonding [282] with a potential relief of anxiety and tension and feelings of connection to a group [283]. This is most typically observed in the one-on-one engagement in dyadic interactions—as in the case of mother and child—but it can be established also in larger group settings throughout the life span [284]. It is possible, however, to broaden this dyadic approach, as well as to conceive of music listening also in terms of wider social interactions, with a special emphasis on the role of socially learned effects of the music beyond the narrower vibrational and naturalistic approach to musical sense-making that was proposed to some extent in this paper.

The major aim of this paper, however, was to reflect on the KMC-to-music translation, with a focus on the dyadic interaction between the music and the listener, which can be investigated in a dynamic-interactive way (see [78] for an overview). There are two major perspectives in this regard: the mother-to-child or child-to-mother interaction. Conceiving of the music as the mother/caregiver, and the listener as the child/care recipient, first, is the more obvious way of hypostasis. It is typically involved in ways of listening that can be subsumed under the "music-as-consolation" category, with music providing the physical touch and quasi-tactile stimulation to the listener. Music engagement, in that case, can be seen as a tool to foster social cognition and affiliative behavior with the pending question of whether such engagement is a learnable skill or the outcome of some dispositional trait. As known from studies on musical chills and thrills, listeners can be assigned either to the chill-responders or non-chill-responders [232,233]. It makes sense, moreover, to consider the need or desirability to intervene in the listener's ways of listening so as to help them to realize these typical responses. This is a challenging question, as it assumes the possibility to modulate the listener's dispositional traits. Yet there is a tentative answer if one takes the perspective that listeners are biological organisms, which have perceptual systems to make sense of the sounding world, together with a nervous system that provides the fine-grained hardware for processing of the sounds. This dispositional machinery, however, is not fixed and stable but is plastic and malleable to some extent [285,286]. This means that listeners can modify both the structure and the functional connectivity between distinct areas of the brain. A major finding in this regard is that reward sensitivity to music is dependent upon connectivity between auditory sensory processing areas and emotional and social processing, as highlighted in an increased tract volume of bundles of white matter in the brain of listeners who frequently experience intense emotions and chills [287].

It is possible, further, to also reverse the direction of the interaction, as well as to conceive of the music as the care recipient, with the music being seen as something the listener should take care of. It is an approach that adheres to the concept of empathic listening and that has even clinical importance in the sense that people with high emotional empathy have higher white matter connectivity, whereas people with social-emotional impairments and functioning have lower white-matter connectivity [288–291]. The social cognition of music, therefore, can be better informed by an understanding of empathy. It facilitates a person's ability to step into the shoes of the performer or composer and to tune into the emotions of other musical participants and audience members [280,292]. Empathy, therefore, may be considered a cornerstone of the social benefits derived from music and its impact on the brain [284].

Both approaches (mother-to-child and child-to-mother) open up perspectives for music education and music therapy, in an attempt to invite listeners to engage with and be involved in the sounds, figuring as a virtual agent. Listening, in that view, is a dynamic process of interaction, but it is also a skill that can be learned, and that can be redefined in terms of skill acquisition, as studied in athletics, sports, and music performance studies. What is needed, however, is a framework that positions music listening at the receptive rather than on the executive level of music processing, with openness to experience and receptivity for subtle and fine-grained quasi-tactile stimulations as modulatory variables. There is, moreover, growing empirical support from neuroscience that the connectivity between distinct regions in the brain plays a role of major importance in this regard, and recent findings in the domain of neuroaesthetics are quite promising in this regard. They seem to confirm, moreover, not only the assumed connections with the processing of reward but also some demonstrable relationship between aesthetic listening and moral decision making. It means that aesthetic judgments share their neural correlates in the reward system with moral appraisal, which points in the direction of common ground [287,293], thus corroborating the "beauty-is-good" stereotype and the old adage that music soothes the soul.

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