

Essay

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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 art that impinges upon 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 bonding with stimuli that elicit reward. Via an extensive review of the research literature, it is questioned 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: vibration; touch; coping; kangaroo care; reward system; musical enjoyment; chills and thrills

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, in this regard, an abundance of music recordings on the internet with “highlights” or “bests of” by famous singers, even with historical performances of performers who 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 comments visitors on the web as “hair-raising, full-bodied singing & psychological portrayal.” Even if the sound quality of these recordings does not meet our current standards of sound reproduction, they can still trigger a cascade of physiological reactions—commonly described as chills and thrills—, on condition that the listener manifests the needed openness and receptivity to being touched by the music.

Music, in fact, has great penetrating power. It is very intrusive and invading, and spans a continuum between acoustic rape, in the case of extremely loud music, and a 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 impinges on the body and the senses as a virtual agent only, and not as living participant in a bodily exchange. The analogy with a mom who cuddles her baby is quite illuminating in this regard. 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 cuddling and sexual contact.

This penetrating power of music, and its potential to influence listeners at a very basic physiological level, has been applied also in the use of sonic weapons to dominate and confuse targets or to destroy the subjectivity of prisoners in the interrogation room. Yet, this same intruding power is sought after by some listeners in their tendency to listen to extremely loud music purely for pleasure (Volcler, 2013). 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].” (Cusick, 2006, p. 6). It typically describes how some 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.

Music, as a vibrational art, may activate the sense of touch (Huang et al., 2012) and the vestibular system in the inner ear (Todd, 1993, 2001; Todd and Cody, 2000) besides the sense of hearing. It means that the experience of music involves the simultaneous activation of several sensory modalities, which makes it such a rich and touching experience. Vibrations, further, impinge directly on the skin, which is the largest sense organ of the body. As such, sound vibrations 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 (Piéron, 1956), challenging to some extent Sherrington’s classic distinction between exteroceptive, interoceptive, and proprioceptive sensations, which 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) (Sherrington, 1948).

This broadened approach to sensory modalities is challenging (see Reybrouck et al., 2019) as it opens up new avenues to a “multisensorial approach” that can be mild or overwhelming. It clearly shows 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 (Imhof, 2002). It means that listeners experience the music not as an external, knowable object—something out there—, but as a dynamic, multifaceted, and multisensorial phenomenon that arises through complex material interactions of their physiology with the sounds (Eidsheim, 2015), with effects that can be described as “devastating, physically brutal, mysterious, erotic, moving, boring, pleasing, enervating, or uncomfortable, generally embarrassing, subjective, and resistant to the gnostic” (Abbate, 2004, p. 514). Music, in that 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. Music, in sum, is “experienced” rather than something that is “reasoned” or “interpreted” (Reybrouck, 2014, 2017; Reybrouck and Eerola, 2017). Or to use Jankélévitch’s terms: the musical experience is “drastic” rather than “gnostic” (Jankélévitch, 2003).

2. A biological toolkit for coping with the sounds

The emphasis on a lived experience is typical of a paradigm shift in recent music/aesthetic research. Inspired by the naturalization of phenomenology, which aims at making experience amenable to natural scientific inquiry (Petitot et al. 1999), it means basically that a phenomenological description cannot suffice to describe and analyze a lived experience. It needs, on the contrary, 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 (Brown et al., 2011). Applied to music, this should mean that music can be defined as a “sound environment” or “sonic landscape” with acoustic cues that are perceived by the listener as being either beneficial or harmful

(Reybrouck, 2015; Welch et al. 2023). Listening, in that view, can be considered a way of sense-making and coping with the sounds.

It is still unclear whether there is some linear-causal relationship between these acoustic cues and their 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, the setting of the listening experience, etc.—which 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 sound and noise exposure during occupational conditions, workplace activities, 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 (Alberti, 2001; Basner et al., 2014; Kujawa & Liberman, 2009; Maschke et al., 2000; Mercier & Hochmann, 2002; Williams et al., 2010). There is, on the other hand, a whole category of sounds, which are labeled as “nature’s white noise”, and which 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 sound of waterfalls, mountain rivers, rain in the woods, the blowing of the wind, the sound of ocean waves, and many others (Gould van Praag et al., 2017).

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 (Fitch, 2006, 2015). At the perceptual level, it corresponds to the ability 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 evidenced in the psychobiological model of empirical aesthetics, which defines aesthetic appreciation as a function of perceived arousal (Berlyne, 1971; North & Hargreaves, 1997; Orians & Heerwagen, 1992). 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. It states that the optimal motivation for a task decreases with increasing difficulty and that the peak level of performance is reached at an intermediate level of stress or arousal (Broadhurst, 1957). Translated to the domain of music, this should mean that the music 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 (van der Zwaag et al., 2011). It makes sense, in that view, to attune listeners to sonic landscapes that provide stimulation in this optimal zone of stimulation—above the threshold of hearing and below the threshold of pain and damage—, allowing them to cultivate adaptive responses to beneficial stressors and to avoid possible distress that could be triggered by harmful stimuli. This does not mean, however, that there should not be any challenge. There is, in fact, the phenomenon that is termed eustress, which represents the pleasant stress of fulfillment while simultaneously avoiding the harmful consequences of damaging distress (Selye (1956, 1965, 1976). As opposed to the phenomenon of 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 (Perrez, 2009). It is a phenomenon that is related somewhat to the concept of optimal allostatic load. The term means literally “stability through change,” and refers to the cumulative wear and tear of the strain of physiological effects of multiple forms of adversity on several organs and tissues, due to the overactive or inefficient management of the stress responses (Sterling et al., 1988). Such strain may provoke risks of pathology, such as organ system breakdown, compromised immune response, cardiovascular dysfunction and disease, elevated cortisol and insulin secretion, accumulation of

abdominal fat, loss of bone minerals, reproductive impairments, decreased neurogenesis, increased neuronal cell death, and associated atrophy in the limbic system (McEwen, 1998; Vago et al., 2012). There is, however, also an “optimal” allostatic load, which entails the successful adjustment and adaptation to the changing conditions of the environment. It includes the maintenance of load indicators in normal operating ranges as well as the release of selected brain opioids— β -Endorphins and leucine and methionine enkephalins—, which have powerful effects in counteracting negative emotions and which favor positive ones (Panksepp, 1981; 1993). The release of dopamine from the catecholamine systems, opioid peptides from the central nervous system, and oxytocin are also important players in this regard (see Ryff & Singer, 1988 for an overview).

Without going into details, it can be stated that the body can rely on a complex mix of organ systems— the sensory, musculoskeletal, nervous, cardiovascular, excretory, the respiratory, digestive, endocrine, integumentary system—, that work together to maintain constancy of the “internal milieu” (Bernard, 1978), by trying to keep the basic “homeostatic level setting” (Cannon, 1932) within safe limits by meeting life-endangering situations with adaptive responses. Such homeostatic regulation is a self-regulating process that emphasizes the dynamic nature of our internal physiology through continuous and ongoing adjustments to respond and adapt to environmental demands. It was described by Selye as the “general adaptation syndrome” (Selye, 1950), which entails multiple interactions with the external environment. They 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 larger, general-purpose system that initiates adaptive expectations about the configuration of the environment and its availability for reward (Alcaro et al., 2007). It relies on a coupling of cortical and subcortical regions—the limbic system and brainstem—, with their accompanying modulatory neurotransmitter pathways, which are responsible for dopamine release (Alcaro et al., 2007). The complex neurochemistry of the mesolimbic dopaminergic system is extremely important in this regard. It shows that the seeking disposition for reward may have hedonic properties in itself, irrespective of the actual attainment of the intended reward. A distinction must be made, however, between “tonic” dopamine release which aims at maintaining a basic level of seeking disposition, and “phasic” bursts of release in response to specific cues such as unpredicted reward, prediction errors, novel stimuli, physical, motivational, or affective salience, and attention shifts, all of which are related to approach behavior (Venkatraman et al., 2017).

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 maternal bond, as an 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 (Carozza & Victoria, 2021; Crucianelli et al., 2019; Mateus et al., 2021).

In what follows we propose to expand the scope of this mother-child bonding to the domain of musical engagement. There has been already a bulk of studies on early *mother-infant interactions*, with a focus on infant-directed singing and interactions (Lense, 2022; Trehub & Trainor, 1998; Trevarthen, 2002) and stress and affect regulation by maternal songs (Cirelli & Trehub, 2020; Trehub et al., 2015). The relation between singing, listening, and tactile stimulation, however, has not yet been explored in depth. Much is to be expected here from research on “entrainment” on the basis of acoustic, visual, and haptic cues as evidenced, e.g., in synchronized group dancing (Chauvigné et al. 2019). 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), 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 (Brown, 2022, p. 248).

3. Immersion, absorption, and strong experiences in music

Music listening can create a feeling of connection with each other and/or with the sounds with distinctive levels of absorption and immersion. Both phenomena are related but are not the same.

Absorption, first, 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 (Høffding, 2018).

Immersion, on the other hand, is a metaphorical concept. It evokes the physical experience of being submerged in water and 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 takes over all attention and the whole perceptual system (McMahan, 2003; Murray, 2017, p. 150). The term, however, has led to several one-sided definitions, highlighting mainly the perceptual aspect of the immersive experience (Agrawal et al., 2020; Witmer & Singer, 1998). A typical example is 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” (Witmer & Singer, 1998, 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” (Calleja, 2007), which has been defined as a state of effortless absorption and narrowed but intensified concentration, so as to get rid of personal problems, to feel competent and in control, to experience a sense of harmony and union with the surroundings, and to lose the ordinary sense of time. The flow experience, moreover, has been conceptualized as a balance between challenges and skills, both being relatively high but neither too difficult nor easy (Csikszentmihalyi, 1975, 1988, 1990). It can even be challenging, but it is equally experienced as being full, joyful, not painful, and emotional. It is, as such, a demanding experience, somewhat analogous to so-called “peak experiences,” which can be described as intense psychological states of highest happiness and fulfillment (Maslow, 1968, and Diaz, 2011 for an overview).

Peak experiences have been reported typically 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” (Gabrielsson, 2011, p. 67). This holds in the first place 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 (Presicce, 2018). 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 former are exemplified typically in listening to extremely loud music, which seems to activate more basic mechanisms of experience, by evoking an amodal kind of perception that goes beyond the boundaries between distinct sensory modalities (vision, audition, smell, taste, touch, ...) and that can be seen as a return to the oceanic feeling or state, as mentioned already by Freud (see Saarinen, 2012, for an overview). This 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 (Dibble, 1995), and which is considered as a source of pleasure to some (Todd & Cody, 2000; Reybrouck et al., 2019).

A somewhat milder analogy has been proposed in the context of neuroaesthetics of music, with its focus on the musical-aesthetic experience, which has been defined by Brattico & 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” (Brattico & Pearce, 2013, p. 49). Such an experience involves an attitude that encompasses aesthetic judgment, aesthetic emotions, and preference, along with some degree of intentionality, affective expectations, and dedicated attention.

There are, as such, many descriptions of the immersive experience, which are used also interchangeably. Quite in general, immersion can be defined as a state of engagement that holds our interest through sensory, challenge-based, or imaginative means (Ermi & Mäyrä, 2005). To do this, it requires 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, disregarding somewhat the real world, losing awareness of external events, and the instigation of temporal dissociation (Salselas et al., 2021). 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 (McMahan 2003). Alternative approaches, therefore, have been proposed, mainly in the field of digital games. One of them is the player involvement model (Calleja, 2001), which considers two basic constituting temporal experiences: macro-involvement, which encompasses those forms of involvement with the game when one is not actually playing (offline), and micro-involvement (online), which encompasses moment-to-moment involvement with the game. The actual involvement, further, should embrace the dimensions of kinesthetic, spatial, shared, narrative, affective, and ludic involvement so as to provide an intensified and internalized experience of what Calleja has coined as incorporation (Calleja, 2007). This new concept has been explored in the domains of virtual, extended, or augmented realities, with gradual transitions between what is considered as being real and virtual—the Reality-Virtuality Continuum (Milgram & Kishino, 1994)—, so as to provide a mix of real and virtual objects or events. They extend beyond the visual domain by encompassing also audio, motion, haptics, taste, and smell (Speicher et al., 2019).

Immersion, further, can be subsumed under one of two dimensions that define our experience, namely participation—either passive or active—, and connection. The latter dimension of connection ranges from absorption to immersion with this distinction that immersion entails a process of becoming physically or virtually a part of the experience itself, while absorption means merely that our attention to an experience is brought to mind (Pine & Gilmore, 1999). 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, the surroundings, and forgetting of oneself (Becker; 2004; Butler, 2004; Fachner, 2023; Herbert, 2013; Vroegh, 2021), 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 one in which one “loses” oneself, either as performer or listener, and in which powerful musical events appear to break down distinctions between self and others, evoking powerful feelings of belonging, cohesion, and shared conceptions of identity (Vuoskoski et al. 2017). 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.

4. Musical enjoyment, pleasure, and reward

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Most of the research on music effects thus far has investigated 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 (Reybrouck, Podlipniak & Welch, 2022). These functions revolve around four functional categories: (i) the mechanisms of pleasure and reward, (ii) the notions of valence and arousal, (iii) the affect-related consequences of music listening, and (iv) the role of affective regulation and visceral reactions to the sounds (Craig, 2009). “Adaptive listening” (see below for the term), then, should entail that listeners do not only listen to the sounds they should learn, instead, to read also the conditions of their body, manage their internal physiology, and direct their behavior toward conditions that make it possible to thrive. The evoked emotions, in this view, 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 (Immordino-Yang & Damasio, 2007). It is an approach that invites listeners to monitor and alter the state of their body to stay within the narrow limits of operating homeostatic set-points, as a kind of self-regulation to adjust baseline physiological values to their preferential default values. This holds, among others, for blood pressure, pulse rate, breathing frequency, body temperature, blood 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 our internal milieu (Billman, 2020; Schneck & Berger, 2010).

There are, in this regard, some lower-level reactions that can be described 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 (Salimpoor & Zatorre, 2013; Barrett et al., 2013; Blood & Zatorre, 2001; Martínez-Molina et al., 2016; Mas-Herrero et al., 2018a; Mas-Herrero et al., 2018b; Salimpoor et al., 2013a, b). Much is to be expected, here, from the biochemistry of emotions and affect, —with a major emphasis on affective bonding (Depue & Morrone-Strupinsky, 2005)—, the neurobiology of pleasure, and the neuroendocrinology of musical reward, studied both in a positive direction in case of hedonic happiness, and in a negative direction in case of pathological conditions of lack of pleasure (Berridge & Kringelbach, 2008; Kringelbach, 2009).

Central in this research is the working of the dopaminergic reward system (Nadal & Skov, 2013), which is only beginning to be unraveled with some depth (Salimpoor et al., 2011; Schultz, 2013; Alcaro et al., 2007; Baskerville & Douglas, 2010; Ferreri et al., 2019). 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 prolactin and oxytocin, and their relation to the release of dopamine (Ben-Jonathan & Hnasko, 2001; Fitzgerald et al., 2008). The

underlying mechanisms are not yet totally clear, and there are even distinct underlying theoretical constructions—such as the reward theory, the homeostatic theory, and a behaviorally-oriented theory—which provide even conflicting results (see Eerola et al., 2021 for a critical discussion).

A major breakthrough, however, has been the emergence of *neuroaesthetics*, which is a challenging new field that tries to explain musical behavior in terms of stimuli, brain physiology, and motor responses (Brattico, 2020; Brattico & Pearce, 2013; Brattico & Varankaité, 2019; Nadal & Skov, 2013; Brown & Dissanayake, E., 2009; Chatterjee, 2010; Leder, 2013; Pearce et al., 2016; Zaidel, 2009). 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 such as dopamine in the generation of arousal, the relation between pleasure and aesthetic reactions, the claim that all aesthetic reactions can be reduced to their biological origins, and the distinction between aesthetic pleasure as a core pleasure that originates in subcortical areas as against conscious liking that originates in higher-level cortical structures of the brain (Zaidel & Nadal, 2011; Liu et al., 2017). 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 (Tinbergen, 1963; see also Fitch, 2015) with the former relating to an explanation in mechanistic terms of biochemistry, physiology, and neural correlates, while the latter refer to longer time-scales and ultimate functions of survival. The role of positive emotions in the appraisal of music should be mentioned in this regard, as they may be helpful in broadening the listener’s behavioral and cognitive repertoire. They exemplify rather convincingly the core assumptions of the *Broaden-and-Build Theory*, which states that positive emotions have an evolutionary role in consolidating and expanding resources by broadening the scope of attention, expanding the existing repertoires of thought and action, increasing the openness to new experiences, and improving 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 (Fredrickson, 2001; Jayawickreme et al., 2012) and are typical, also, of the adaptive nature of positive and negative affect (Dickinson & Balleine, 2010; Fredrickson et al., 2008; Nesse, 2004).

Music, in this view, can be used 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 sympathetic and parasympathetic activity of the autonomic nervous system (Peck et al., 2016; Brattico & Varankaité, 2019, Kringelbach & Berridge, 2017, Chanda & Levitin, 2013). This is exemplified most typically in the musical-aesthetic experience, which is characterized by three major outcomes: (i) the experience of typical aesthetic emotions, such as chills, nostalgia, awe, and being moved; (ii) judgments and evaluations of the formal structure and perceived beauty of the music; and (iii) a verdict of liking or disliking of the music (Brattico & Pearce, 2013).

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The question can be raised, in this regard, to what extent the experience of beauty or aesthetic reactions in general must be considered as generic survival strategies, rather than specific reactions to a constrained subset of the environment. There is, as yet, 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. Or stated in other terms: the responses to objects of art overlap with those that monitor the appraisal of non-art objects of evolutionary importance, such as, e.g., the desirability of food and the attractiveness of potential mates (Brown et al., 2011). Aesthetic processing thus seems to co-opt those neural systems that subserve more general “adaptive” assessments, which suggests that the underlying neural mechanisms are 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 (Zaidel et al., 2013).

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 be raised to the standards of a “science of pleasure” (Berridge & Kringelbach, 2008; Leknes & Tracey, 2008), which has seen already an upheaval in the study of the brain mechanisms of pleasure, which are similar in most mammalian brains (Berridge & Kringelbach, 2008; Leknes & Tracey, 2008). 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 with pendants in the hedonic or eudaimonic schools in hedonic psychology (Cooke et al., 2016; Lent, 2004): hedonic pleasure revolves around being relaxed, avoiding problems, and being happy, with a primary orientation towards the satisfaction of homeostatic needs—such as hunger, sex, and bodily comfort—, and with a narrow focus on the experience of pleasant feelings and the avoidance of pain (Jayawickreme et al., 2012; Seligman & Csikszentmihalyi, 2000; Ryan & Deci, 2001; Diener et al., 1999); eudaimonic enjoyment, on the contrary, can break through these constraints and aims toward broader goals that go beyond immediate satisfaction, such as 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, and pathological conditions of lack of pleasure—as in anhedonia or dysphoria—, may function as major obstacles to happiness. They are, as such, quite informative for the study of the underlying mechanisms of happiness. Hedonic happiness, furthermore, may function as a contributing but not constitutive condition for eudaimonic enjoyment. Four possible combinations of their contributions have been identified in this regard: hedonia and eudaimonia occurring together, hedonia without eudaimonia, neither hedonia nor eudaimonia, and eudaimonia without hedonia (Lent, 2004; Waterman, 1990a, 1990b). 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 it does happen, they involve the same hedonic brain systems, which are distinct from those involved in sensation and thought (Berridge & Kringelbach, 2008). They seem to contribute to the broader category of well-being, which embraces both aspects (Ryan & Deci, 2001).

This search for pleasure is a major incentive for music listening here (see Reybrouck & Brattico, 2023 for an overview). Espousing the centrality of hedonic well-being in the search for a balanced equilibrium between positive and negative affect has become even a major part of affective neuroscience, which studies the generation and identification of affective reactions in humans and animals. As a science, it is concerned with measurable aspects of behavioral, physiological, and neural reactions, as well as the more subjective experiences of conscious affective feelings (Berridge & Kringelbach, 2008; Leknes & Tracey, 2008). Of central importance, in this regard, is the finding that neural activity in the reward center is a key component of both hedonic and eudaimonic listening.

5. 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, moreover, 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 doesn't undo the trivial fact that the first level of musical engagement is a sensory experience. This means that, on a primordial level, all our perceptions and engagements with the world are passively motivated by the sensing body. This is not synonymous, however, with being inactive. It refers, on the contrary, to the fundamental openness to the world, with a lived body that actively constitutes multiple relationships with its environment (van der Schyff et al., 2022). There are, however, 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 role 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 to learn to read the conditions of the body and to respond accordingly via the machinery of emotions, which have their basis in certain physiological states (Immordino-Yang & Damasio, 2007; Filippi et al., 2017).

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 (Flohr & Hodges, 2002). It means that listeners should attune themselves not only to the music as an external stimulus, but also to the physiological responses of their body, even if these are not always manifest (Reybrouck et al., 2022). 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 efforts have already been done already to measure the physiological and neurological correlates of music listening. The findings 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 third-person and first-person descriptions of consciousness (Varela & Shear, 2002; Zahavi, 2005; Lutz et al., 2002). The objective measurements (third person: this music has these characteristics) can be reduced to behavioral and brain-based measurements in an attempt to track the graded nature of consciousness, with a distinction between both unconscious and conscious processing (Seth et al., 2008); the subjective appraisals, on the other hand, entail descriptions which are tailored to individual listeners (first person: I experience this music as ...). The combined approach of both first- and third-person perspectives, however, has been successfully implemented in the emergent field of neurophenomenology, which tries to enrich the theoretical perspectives of phenomenology by relying on the tools of neuroscience and experimental psychology (Varela, 1996; Lutz, 2002; Lutz & Thompson, 2003; Thompson, 2004). There is, however, still another perspective, which is still waiting for additional empirical support, namely the second-person approach (Gallagher & Zahavi, 2008; Høffding, 2018). This holds when we are engaged in mutually responsive interactions and where other persons appear as an immediate "you" rather than as a detached third person or object (Froese & Leavens, 2014). It is a kind of direct perception of other minds, without explicit theorizing, imagining, inference or simulation, relying mainly on bodily interaction (Kojima et al, 2017). This bodily approach, however, is distinct from common conceptions of social cognition in terms of theory of mind, mentalizing, or mindreading, which all claim that an individual imputes mental states—such as beliefs, desires, intentions, goals, experiences, sensations and emotion states—to himself/herself and to others (see Overgaard & Michael, 2015, 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 it even as a virtual agent. Its traveling energy, however, is not virtual; it impacts the whole body—cells, organs, tissues, and more encompassing organ systems (Schneck & Berger; 2010)—to arouse physiological responses, which may be either positive or negative. The latter have been the subject of multiple studies—oriented primarily oriented to the negative impact—in the domain of vibroacoustic medicine (Gerber, 2001), which studies the effects of vibrational energy that the body immediately senses and to which it responds way by all kinds of psychological and mental connotations. Some of the negative effects

have been assigned to the umbrella term of vibroacoustic disease (Castelo Branco et al., 2002; Alves-Pereira and Castelo Branco, 2007), which embraces those symptoms that have been found in people exposed to low-frequency noise with large pressure amplitude as part of their everyday environments (Maschke, 2004). The findings have uncovered lesions in several organs—the nervous system, heart, blood vessels, lymphatics, and respiratory tissues—, together with tissue reorganization and neo-formation (da Fonseca et al., 2006; Alves-Pereira & Castelo Branco, 2007). More in particular, fibrosis has been found in connective tissue and exposed organs, which points in the direction of a protective response of the tissue by increasing the production of elements with a structural role and viscoelastic properties, so as to resist the impact of strong mechanical stress (Oliveira et al., 2013).

The vibrational responses, however, are not always harmful or annoying. Recent research has broadened the field of research by exploring also the role of adaptation to vibrational energy, with a central focus on the concepts of physiological entrainment and resonance (Reybrouck, 2023). The phenomenon of entrainment, in particular, is a hot issue in current research (Clayton et al., 2005; Pantaleone, 2002; Roenneberg et al., 2010; Secora Pearl, 2005). 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 a rate that is imposed by the person who dribbles the ball. 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 (Schneck & Berger; 2010).

It is not difficult 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 which 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 (Pallasmaa, 2005). 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 (Reybrouck, 2017).

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 realm of music, this is obvious in playing or singing together, particularly in dyadic settings but also if 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. This 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 which 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) approach. Besides these interpersonal perspectives, there is also a multiplicity of sensory stimulation, 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 (Hove & Risen, 2009; Demos et al., 2012). 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 (Haslam et al., 2014; Koball et al., 2010; Pearce et al., 2015; Clift & Hancox, 2001; Grindley et al., 2011; Joseph & Southcott, 2014). Choir singing, moreover, seems to facilitate the establishment of social bonds, due to the shared intention, attention to, and achievement of a collective goal (Launay et al., 2013, Launay et al., 2014; Reddish et al., 2013; Wolf et al., 2015), but also to the endorphin release that is triggered by synchronous activity (Dunbar et al., 2012; Tarr et al., 2014; Tarr et al. 2015). 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. might be a strong marker of successful coordination and synchrony to produce a collective product, which makes singers feel more integrated in the group.

6. Being moved by the music: chills and thrills

Resonating with the music is not merely a physical phenomenon. There are derived effects that are commonly referred to as the inductive power of music (Reybrouck & Eerola, 2017). They revolve around evoked emotions and affects, with a whole system of mappings between the music and the listener, which can be seen both as a resonating physical body and as a subjective human being. There is, however, a lot of variability among individual listeners, both in the frequency and the specificity of their aesthetic responses, which makes it difficult to generalize about the evoked effect. Yet it is possible to distinguish some common characteristics in the bulk of music-induced emotions and affect. Two major categories 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 are the subject of interesting empirical studies in the sense that there seems to be at least some causality in the mapping between the eliciting stimuli (the music) and the induced responses (psychophysiological reactions), which lend themselves rather easily to objective measurement and assessment.

The arousal-enhancing effects, first, are related to the definition of music as a vibrational phenomenon. Sound waves are physical disturbances which can put stress on the body and the brain. As such, they can have a role in the modulation of the homeostatic balance. In the worst case, this can become a source of allostatic load (Reybrouck, Podlipniak & Welch, 2019, 2022), which is the strain on our organs and tissues as the result of repeated fluctuations in physiological responses to perceived threats and forms of adversity (Sterling & Eyer, 1988). Two possible outcomes have been identified in this regard: (i) acute shifts in physiological reactivity in response to specific stimuli, and (ii) chronic and cumulative elevations of level settings outside of the basal operating ranges, which operate in the absence of the threatening stimuli (Ryff & Singer, 1988). This cumulative strain can, in the long term, lead to organ breakdown, reduced immune response, elevated cortisol and insulin secretion, and finally also disease (McEwen, 2008). The main effects are reflected in biological stress responses by the neuroendocrine, autonomic, and immune systems, which put high strains on the mobilization from the hypothalamic-pituitary-adrenal axis (HPA) and which activate the sympathetic branch of the sympatho-adrenomedullary system, with a corresponding cascade of hormones—such as corticotropin-releasing factor, corticotropin, and cortisol (Chanda & Levitin, 2013; Kays et al., 2012; Reybrouck et al., 2021).

Listeners can thus behave as biological beings who rely on their neural apparatus for coping with the sounds. Listening, however, is not merely reactive, but 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 harmful and annoying. It is the basic mechanism of coping behavior that evaluates the environment in terms of threats and dangers, as well as its possible benefits for survival (Reybrouck et al., 2020).

This brings us to the second category—chills and thrills—, which embrace, among others, feelings of sadness, being touched, tenderness, and being moved (Eerola et al., 2018; Ladinig et al., 2021; Zentner et al., 2008; Cova & Deonna, 2014; Konečni, 2005; 2015; Kuehnast et al., 2014; Menninghaus et al., 2015). The latter, in particular, plays a major role in the neurochemistry of emotions. Being a mixed but predominantly positive emotion, being moved has been linked to prosocial and social-bonding behaviors (Huron & Vuoskoski, 2020) 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, on the contrary, is modulated also by their musical preferences and learning history rather than relying merely on acoustic triggers (Grewe et al., 2007).

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 regarded as unified constructs or as sets of distinct responsive 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 a new-found insight, with feelings of tension, awe, and sublimity. Chills, as the more restrictive category, have been related to absorption and being moved (Bannister, 2019; Pelowski et al., 2017).

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7. Adaptive coping and homeostatic regulation

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The concept of coping is quite enlightening in this regard. 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” (Lazarus, 1984, p. 141). It can be illustrated most easily by describing the way how 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 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 are not able 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 primarily designed to provide rapid availability of the needed energy in case of danger and stress (Maschke et al., 2000). They are typically exemplified in arousal-inducing defensive responses to fear and stress, such as the

acoustic startle reflex, the orienting response, the fight and flight reaction, and to some extent also the myogenic vestibular evoked potentials (Bernstein, 1968 1979; Błaszczyk, 2003; Salloum et al., 2014; Todd et al., 2000), 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 (HPA) axis, which triggers a release of adrenocorticotrophic hormone (ACTH) and cortisol concentrations above baseline levels with a heightening of the arousal level in general (Davis et al., 2008; Bradley et al., 2006; Lang & Davis, 2006; Parker et al., 2011). 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 (Ryff & Singer, 1988).

The coping mechanism has a lot of explanatory power as it provides a subtle balance between the avoidance of harmful stimuli and the search for positive and rewarding ones. Coping, however, is not merely a physiological reaction to the sounding stimuli; it involves also a way of sense-making of the surrounding sonic world, with a multiplicity of reactions, ranging from overt physical reactions to affective-emotional reactions to cognitive and mental operations (Reybrouck, 2001; 2005). This entails the possibility of a “mediated” way of coping, modulating the experience and turning negative estimations into positive ones and vice versa, somewhat related to the way how human beings exert power and control on their environment. This echoes the principles 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 (Rogers, 1970, 1994).

The concept of adaptive listening is quite promising in this regard. It goes beyond a mere 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 by giving attention also to the nature of health and well-being (Cooke et al., 2016). 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 aim instead at the pursuit of aesthetic enjoyment, which is characterized by a potential interaction with the eudaimonic networks. 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 (Damasio, 2004), that activates the neuroendocrine responses that are connected to the reward center and the hedonic hotspots of the brain. The other side of the coin is maladaptive listening, in which case the music is experienced as a possible stressor, even if the listener experiences it as enjoyable (Welch & Fremaux, 2017a, 2017b). 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—e.g. screaming, scratching, or breaking glass—, which may selectively activate the amygdalae, which mediate between the threatening stimuli and defense reactions of the body (Koelsch & Skouras, 2014; LeDoux, 2017; Filippi et al., 2017), and also for music that provides stimuli outside of the range of optimal stimulation, as in the case of extremely loud music. But even beyond these acoustic descriptors of stressful stimuli, it is possible to conceive of maladaptive listening when music is listened to for mood regulation but without real enjoyment of the music, or when no psychological benefits are obtained from listening (Garrido & Schubert, 2013; Miranda & Claes, 2009). It means also that the search for reward is not the ultimate aim of listening in that case, with, instead, 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 (Hsee et al., 2003; Jayawickreme, Forgeard & Seligman, 2012). 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 normally serve reward-related learning and that involve the dopaminergic circuits of the brain (Hyman et al., 2006).

Music, as a stimulus, can thus be a source of pleasure and enjoyment, but it can be experienced as a possible stressor as well. Taking a biological perspective, further, it is possible to conceive of adaptive and maladaptive ways of coping with the sounds, with a search for reward and hedonic stimulation on the one hand, and the avoidance of homeostatic dysregulation on the other. Both ways of listening can be defined in operational terms as ways of coping that try to stay within the constraints of basic homeostatic level setting (adaptive) as against those that challenge this protective mechanism by probing the boundaries of optimal stimulation (maladaptive).

It is possible, however, to broaden this biological perspective, and to conceive of coping also in more behavioral terms as approach or avoidance. This approach/avoidance dichotomy has yielded a lot of theoretical frameworks and empirical research (Ryan & Deci, 2001), 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 narrow conception of hearing as an acoustic warning system in favor of a definition of coping as optimal navigation in the environment in search of opportunities in the world at large (Orians & Heerwagen, 1992). Such redefinition of coping behavior includes the search for pleasure and enjoyment in an attempt to go beyond the management of physiological responses and to generalize from fundamental sensory pleasure or positive affect to the larger hedonic brain mechanisms that contribute to happiness. It is an approach that fosters a shift from mere hedonic responses to auditory stimuli to the appreciation of a full-fledged aesthetic experience (Brattico & Varankaité, 2019; Kringelbach & Berridge, 2009).

The aesthetic experience and the implied experience of beauty, however, is still a controversial point. Even if there is a long tradition of reducing aesthetics to the “art of beauty” and the “sublime”, the mere category of beauty does not embrace the fullness of an aesthetic experience. What is needed, on the contrary, is a broadening from a rather limited focus on phenomena that are positively valued—as advocated in the aesthetics of Enlightenment—to span a continuum from negative emotions such as dislike and disgust to positive ones, such as awe and ecstasy (Brown et al., 2011). There are, moreover, distinct aesthetic emotions, such as wonder, transcendence, tenderness, nostalgia, peacefulness, power, joy, tension, and sadness, as embodied in the Geneva Emotional Music Scale (GEMS). (Scherer & Zentner, 2008; Zentner et al., 2008), which differ from so-called utilitarian emotions by occurring in situations that do not by themselves trigger self-interest and goal-directed action. Among the aesthetic emotions, three of them—awe, nostalgia, and enjoyment—have attracted the most substantial research, and aesthetic awe, in particular, has been identified as a crucial characteristic that sets peak aesthetic experiences apart from everyday casual experiences (Gabrielsson, 2011). Such musical peak experiences can be strong, with high levels of arousal, but they can be mild as well, as in the case of chills and thrills. The metaphor of being “touched” by the music, in particular, may be taken almost literally, with music not only stimulating the ears but impinging also on the skin, as the touch-sensitive organ par excellence. The phenomena of goose-bumps and hair-rising (pilo-erection) and the more poetic term of skin orgasm (Panksepp, 1995; Harrison & Loui, 2014) all point in the direction of a strong coupling of the auditory and tactile sense. It raises the question of to what extent music can be considered as a kind of substitution for skin-to-skin contact. It brings us to the title of this paper: can music listening be considered a kind of kangaroo care in some derivative way?

8. Music listening and kangaroo care: celebrating the sense of touch

The metaphor of being touched by music is widespread and almost universal. Yet there has been little empirical research into the actual relationship between listening and the sense of touch. Touch, especially when it applies to human beings, is still somewhat tabooed when it comes to empirical research. It is typical of a culture of the image, in which the appeal to the sense of touch is visual rather than tactile. Touch, in this view, is consumed by the eyes and the ears rather than by tactile gratification. Hence perhaps the need for cocooning with the aim to create a safe, enclosed bubble to compensate for comfort that is lacking to some extent in the outside world. (Classen, 2020b, Fingerprints2). Tactile culture, however, is everywhere but has often passed under the radar in the academic world. There are however fascinating perspectives on the role of tactility in general, and in

the arts in particular (see Classen, 2020a for an overview) with several scholars having bucked the trend in an attempt to take up to provide specific issues about tactile culture (Gowing, 2003; Harvey, 2002; Sedgwick, 2003). The sense of touch was taken up also by several French philosophers in the 20th century (Deleuze and Guattari, 1987; Derrida, 2000).

Touch, moreover, has many faces, ranging from the brutality of a physical blow to the most sensual caress, but quite in general, it can be considered as a kind of tactile communication and contact, which, due to the immediacy of touch, expresses more profoundly and instantly what language can only confer at length. This is exemplified, most typically, in mother-child interactions with preverbal children.

It is challenging, therefore, to explore the significance of maternal touch besides vocalizing, and to conceive of the “mother touch” as being complementary to the “mother language” (Classen, 2020b). As such, it has become an issue in healthcare in general and in childcare, with newborns as the preferential subjects of study (Synnott, 2020). Touch, in fact, is a powerful tool in the interactions between human beings, with conspicuous potential for aggression, sex, and physical coercion, thus representing the most direct invasion in the “bubble of privacy” that people maintain around themselves (Finnegan, 2020). This intrusion, however, can be also beneficial, provided that it is wanted and enjoyed. Touch, in that case, does not only function as a compensatory mode for shortcomings of other sensory modalities—as in the case of blind people who rely more strongly on tactile exploration—; it may become even a primary mode of communication as exemplified in the physical closeness of mothers with their newborn babies.

This tactile approach has long been neglected in academic circles, but it has gained some importance in clinical settings, with caregivers and clinicians starting to recognize the psychological and physiological value of tender touch. Affectionate tactile stimulation, however, has a long history of being discarded in the context 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 (Montagu, 1978, 1979).

This “tactile turn” has gained even more momentum in the neonatal context of preterm infants with evidence-based beneficial effects of so-called kangaroo mother care (KMC). 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—, this 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 (Ludington-Hoe, 2011b). It is, as such, a non-invasive, supportive, and natural early intervention for preterm infants, who, due to the limited closeness in the clinical setting of the neonatal intensive care unit, with the baby being put in an incubator, could benefit from additional threads of sensory stimulation—olfactory, auditory, tactile, thermal, and proprioceptive—provided by the mother (Dombrowski et al., 2000).

The technique of KMC was described for the first time in 1978 in Bogotá (Colombia) as an alternative method for low birth weight infants’ care, with the aim to compensate for the negative effects of the physical separation of the mother from the infant and to provide the physiological stability, neurobehavioral organization, feeding success, and socio-emotional benefits of close physical contact. 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 (Hofer, 1995). The phenomenon, moreover, in a more pronounced form, is known as separation distress or separation anxiety. It reflects a basic neurobehavioral anxiety system that acts as a motivator to restore the distress of social isolation, rejection, and psychic pain via reintegration into a social group (Depue et al. 2005; Eisenberger et al., 2003).

Early skin-to-skin care, provided by the parent’s body, is seen as the most prototypic affiliative bonding with specific stimuli that activate reward in both the mother and the infant (Di Chiara & North 1992). Tactile stimulation seems to be particularly effective in activating affiliative reward processes through the release of some sociosexually-related hormones. Light 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 (Depue et al. 2005). Skin-to-skin care, therefore, seems to be 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, and gives support for physiological stability, neurobehavioral organization, and positive attachment relationship (Browne, 2004). The parent's body can be seen as the most optimal, appropriate, and physiologically stabilizing environment for these infants.

The KMC method has proved to be surprisingly successful and has since spread also across more developed countries. The rationale behind its approach 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 (Anderson et al., 2003). The transition from fetal to neonatal life, in fact, is a most dramatic and potentially hazardous event, with 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—of the term infant to enhance stabilization and facilitate adaptation to the outside world (Ferber & Makhoul 2004; Feldman & Eidelman, 2003). Kangaroo care is supposed to intervene in the maturational rates of neurodevelopment at that early stage by integrating the rhythmic, thermal, and sensory components of the mother's physical presence, which, in turn, can affect the autonomic functions, state regulation, and orienting behavior. Or stated differently, kangaroo care can help the newborn with self-regulation in the presence of incoming information from the outside world by providing maternal contact to establish a kind of protective function by raising the protective threshold or “stimulus barrier” for potential aversive stimuli (Ferber & Makhoul, 2004). As such, kangaroo care seems to facilitate the first phases of transition from the intrauterine to the extrauterine world, providing a smoother neurologic adaptation after delivery.

Tentative findings also point towards beneficial effects of KMC not only for the baby but also for the mother (Mori et al. 2010; Kostilainen et al. 2021). The benefits are rather promising. KMC has been found to reduce mortality, illness, tolerance to pain, infection, and length of hospital stay for the baby (Jefferies, 2012; Conga et al., 2009). It seems also to trigger an enhanced neurological development, with accelerated autonomic maturation, as evidenced by gains in the vagal tone (Feldman et al., 2003). Besides, it seems to facilitate better mother-infant bonding and a feeling of comfort for the mother (Roller, 2005; Badiie et al., 2016).

In a broader sense, KMC should not be reserved for preterm babies. It can be applied also 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 (Ludington-Hoe, 2010; Ludington-Hoe, 2011a). KMC should also not be restricted to maternal contact but should be extended to fathering behaviors. It has been found, in fact, that paternal holding and contact with infants can trigger multiple hormonal responses, such as increases in prolactin, vasopressin, and oxytocin levels, as well as a decrease in testosterone values (Cong et al. 2015, 405).

This ventral contact—chest-to-chest—provides pleasing tactile stimulation of tactile afferent nerve fibers, with the release of oxytocin as a critical factor (Olausson et al., 2010; Uvnas-Moberg et al., 2005; Ferber & Markhoul, 2004), as it modulates brain and systemic changes in both the baby and the care provider (Gordon et al., 2010; Uvnas-Moberg, 2003; Cong et al., 2015). Oxytocin release, in particular, seems to play a mediating role in the optimal parenting of pre-term infants (Uvnas-Moberg et al., 2005)]. Oxytocin (OT) is synthesized primarily in the hypothalamus with direct projections to the pituitary, from where it is released into the bloodstream. This is the neurosecretory component of the OT system, which is known as the neurohypophyseal OT system (Ross et al. 2009, 1?). Being a mammalian neuropeptide, OT has an important role in birth and lactation, but it has been found recently also to function as an oxytocinergic system that plays a major role in attachment bond formation and parenting (Ross & Young, 2009).

Maternal–infant contact and touch thus stimulate the release of oxytocin, which, in turn, leads to the promotion of increased maternal–infant proximity (Maestriperi et al., 2009). It echoes the early neurobiological perspective in animal studies that all forms of social bonding are modulated by this mammalian neuropeptide (Insel, 1992, 1997), and is a key feature of attachment theory. Being one of the most productive areas of developmental psychology, this theory investigates the innate propensity for attachment and bonding, its physiological and behavioral correlates, the outcomes of secure and insecure attachment, and the factors associated with disturbances in attachment formation (Bowlby, 1969, 1973, 1980, and Feldman et al., 1999 for an overview). It revolves around the three concepts of attachment, separation, and loss—operationalized in terms of the degree of closeness or distance from the mother—, and has been largely inspired by the empirical and theoretical framework of ethology with major tools for theory building such as observation, assessment, and hierarchical categorization of bonding behaviors (Bretherton, 1985; Hofer, 1995).

Kangaroo care, further, can be provided in pure form, being restricted to mere tactile contact. It is possible, however, to provide also skin-to-skin care and music together (Teckenberg-Jansson et al., 2011), either by allowing the mother to sing in person or using recordings of her voice, to add additional sensory modalities which may be helpful in building connection with the baby either by maternal singing (Arnon et al., 2014), recorded music (Lai et al., 2006), and live music (Schlez et al., 2011).

Using the mother's voice, in particular, is a well-established method to improve postnatal development, with beneficial effects on behavioral and systemic outcomes such as feeding, autonomic stability, cardiorespiratory regulation, and neurobehavioral development (DeCasper & Fifer, 1980; Fifer & Moon, 1994; Chorna et al., 2014; Krueger et al., 2010; Picciolini et al., 2014; Rand & Lahav, 2014; Doheny et al., 2012). These empirical findings lend support to the universal and cross-cultural use of the mother's voice to soothe infants and engage in early interaction and communication. This kind of vocalization—known as infant-directed singing—aims at intrinsically soothing the child and 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 draw the infants' attention towards the caregiver (Smith & Trainor, 2008; Trainor, 1996; Fancourt & Perkins, 2018). It should be seen as a means for affiliative bonding, which can be broken down into three core processes, namely the appetitive and consummatory phases of reward processes, and the formation of affiliative memories as the outcome of the reward processes. (Depue & Morrone-Strupinsky, 2005). The underlying neurochemistry of the first processes, in particular, is quite revealing, with a major role for dopamine in the appetitive phase, and the release of endogenous opiates (endogenous B-endorphin) as part of the consummatory phase of affiliation. The latter is typically accompanied by a state of physiological quiescence and behavioral calmness subjective feelings of liking and pleasure (Berridge, 1999).

There is currently substantial grounding 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 (Gingrich et al. 2000). Affiliative behavior, furthermore, is not gratuitous. It enables physiological adaptations that facilitate so-called trophotropic processes—such as calmness, relaxation, digestion, metabolism, growth, and healing—, and it may even foster the physiological coregulation of bonding partners (Uvnas-Moberg 1998; Porges, 2001). It can be argued, therefore, that basic associations can be defined between affiliative stimuli, neurobiology, and neurochemistry (Depue et al. 2005, 345). 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. 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 (Depue et al. 2005).

Summarizing and expanding a little, KMC is an intervention that brings the child into, direct contact with the mother. It is skin-to-skin, but it can be seen also as the ideal way to transmit maternal sounds as well, and this holds, in particular, in the case of singing (Arnon et al., 2004). KMC and music, moreover, are well-established, safe, inexpensive and easily implementable methods. 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 to 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 quite new avenues for music education and music therapy in clinical settings. What is needed, is a kind of 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 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, and what are the underlying mechanisms that can modulate the responses to the music.

9. Conclusion and perspectives

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 neurosecretory processes, hedonic pleasure and eudaimonic enjoyment, and adaptive and maladaptive coping. Besides, 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 (Carter, 2014; Baskerville & Douglas, 2010).

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 art. 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 starting point of this article was therefore twofold with 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, and which makes 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 (Greenberg et al. 2021, 1173). 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 a sense of “groupishness” and “cohesion” (Brown, 2000). It is a hypothesis that is grounded in evolutionary claims of music as related to the facilitation of social bonding (Savage et al., 2021) with a potential relief of anxiety and tension and feelings of connection to a group (Dissananyake, 2007). 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 (Greenberg 2021). The 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 Reybrouck, 2023 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 (Bannister, 2019; Grewe et al., 2007). 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 (Reybrouck et al., 2018; Reybrouck & Brattico, 2015). 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 (Sachs et al., 2016).

It is possible, further, to reverse also the direction of the interaction, and 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 (Johansen-Berg, 2010; Parkinson & Wheatley, 2014; 2004; Johnstone & van Reekum, 2007; Mas-Herrero et al., 2014). The social cognition of music, therefore, can be better informed by an understanding of empathy, which 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 (Greenberg, Rentfrow et al., 2015; Livingstone & Thompson, 2009). Empathy, therefore, may be a cornerstone of the social benefits derived from music and its impact on the brain. (Greenberg 2021, 1175).

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, thus pointing in the direction of common ground (Avram et al., 2013; Sachs et al., 2016), thus corroborating the “beauty-is-good” stereotype and the old adage that music soothes the soul.

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