Two-Level Model of Embodied Cognition in Music

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ABSTRACT

In this paper, I propose that embodied cognition in music has two distinct levels. The "surface" level relates to the apparent corporeal articulation such as the activated psychomotor program of a music performer, visible gestures in response to music, and rhythmic entrainment. The primary (though concealed) "deep" level of embodied cognition relates to the main coding aspects in music: the tonal relationships arranged in time. Music that we love – for example, a favorite melody – is made of combinations of a small number of basic melodic intervals that differ by their psychophysical characteristics, among which the level of tonal stability and consonant-dissonant dichotomy are the most important for the formation of tonal expectations that guide music perception. Listeners perceive music as a flow of tonal relationships arranged in time; the temporal and tonal dimensions are interwoven and constitute the tonal chronotope. The intuitive navigation in artistic tonal time-space relies on tonal expectations that are at the heart of melodic intentionality and musical motion. Melodic intentionality has its foundations in artfully sequenced tonal tension and release from tension. Significantly, perceived tonal tension is related to real physical tension. In a music listener, the patterns of perceived tonal tension most likely generate corresponding patterns of physical tension that contribute, along with other musical aspects, to forming a musical emotion, or the experience of psychological time in music. The tonal/temporal relationships encode musical content that dictates the motor behavior of music performers. The proposed two-level model of embodied cognition connects core musicology with the data from studies in music perception and cognition as well as studies in affective neuroscience and musicianship-related brain plasticity. The paper identifies the need for collaboration among various subdisciplines in musicology and cognitive sciences in order to further the development of the nascent field of embodied cognition in music. The presented discourse relies on research in the tonal music of European tradition and it does not address either aleatoric music or the exotic musics of non-Western traditions. To make the proposed model of embodied cognition in music available for nonmusicians, the paper includes the basics of music theory.

It is cruel, you know, that music should be so beautiful. It has the beauty of loneliness of pain: of strength and freedom.

Benjamin Britten

What is the source of these instinctive feelings, these vague intuitions and introspective sensations?

Charles Ives

The concept of embodied cognition proposes that sensory-motor experiences shape human consciousness (Clark & Chalmers, 1998; Damasio, 1994, 1996; Lakoff & Johnson, 1999; Merleau-Ponty, 1945/2012; Varela, Thompson, & Rosch, 1991). Studies show that some sensory modalities of perception could be damaged or lost if they are not activated during the critical/sensitive period of early development (Hensch & Bilimoria, 2012; Hensch, 2016; Hubel & Wiesel, 1970). According to Nikolai Lobachevsky, "[I]n nature, we know only the movement itself, without which sensory impressions are impossible" (Lobachevsky, 1829/1912, p. 13). As fort the ability to move, Kolb and Whishaw (2015) write, "we can think of the entire nervous system as the motor system, because the nervous system functions to move the body" (Kolb & Whishaw, 2015, p. 232). The genesis of the theory of embodied cognition has also involved studies in mirror neurons (Aziz-Zadeh & Ivry, in press), proprioception (Cole & Montero, 2007; Overy & Molnar-Szakacs, 2009), and the relationships between motor behavior and language (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Hostetter & Alibali, 2008; McNeill, 1992).

At the center of the discourse on embodied cognition is the concept of consciousness (Chalmers, 2000; Chemero, 2009; Damasio, 1999; Edelman, 1992; Prinz, 2009). Two neurobiological models of human consciousness are especially relevant for discourse on music cognition: the model of the principal functional units of the brain by Luria (1973) and the model of a triune brain by MacLean's (1952, 1990). The triune brain model explains the hierarchy of consciousness as comprised of the reflex-complex, limbic system, and neocortex. The reflex-complex (reptilian brain) involves the primary forms of consciousness – raw perceptions and feelings. The secondary forms represent the affective consciousness of pre-linguistic awareness and emotional reasoning; their neurobiological home is the paleomammalian brain that is also referred to as the limbic system (MacLean, 1952). The tertiary forms support abstract reasoning, imagination, and the purely human ability to think about thought by using the complexity of linguistic language. The neurobiological mechanisms of thinking are still not clear and the consciousness is currently explained as an emergent property (O'Connor & Wong, 2015), which is supported by extraordinary complex interactions of neural networks (Buzsaki, 2011; Fingelkurts & Fingelkurts, 2013) forming a connectome (Seung, 2012).

According to the model of the triune brain, musical consciousness exemplifies the secondary forms of consciousness, or affective consciousness (Panksepp, 1998, 2005). The art of music is nonrepresentational and therefore categorically different from such system of communication as linguistic languages that use words as "constants of consciousness" (Solntsev, 1974) to convey information in precise ways. For example, despite the diversity of human languages, the representational nature of linguistic communication allows for translation of information from one language to another with considerable accuracy. Communications by music are colloquially termed the *language of emotion*, and there is a general agreement that music elicits emotions (Juslin & Sloboda, 2010). According to Cosmides and Tooby, emotions are superordinate programs that affect our consciousness and orchestrate our behavior (Cosmides & Tooby, 2000). The experience of emotions involves bodily reactions, including changes in heart rate variability (McCraty & Shaffer, 2015). Loss of motor functions, and the corresponding reduction in the activity of sympathetic nervous system, reduces the emotional responsiveness (Mack, Birbaumer, Kaps, Badke, & Kaiser, 2005). Researchers studying emotional processing divide emotions into two subgroups: basic, or utilitarian, emotions and aesthetic emotions (Scherer & Zentner, 2008).

In music we deal with aesthetic emotion. Empirical studies demonstrate that music is able to influence the psychophysiological state of listeners by producing chills (Panksepp & Bernatzky, 2002; Sachs, Ellis, Schlaug, & Loui, 2016), by activating the biological reward system (Blood & Zatorre, 2001), and by generating changes in vital signs (Bernardi, Porta, & Sleight, 2006; Möckel, Röcker, Störk, Vollert, Danne et al, 1994; Iwanaga & Moroki, 1999; Krumhansl, 1997). Studies in emotional processing in music generally focus on the main morphological aspect of music – the tonal relationships (Lerdahl, 2001; Lerdahl & Krumhansl, 2007). These studies investigate the responses to the major and minor modes (Gagnon & Peretz, 2003; Hevner, 1935, 1936; Kastner & Crowder, 1990; Trochidis & Bigand, 2013; Virtala & Tervaniemi, 2017; Webster & Wier, 2005), the perception of tonal modulation (Firmino, Bueno,

& Bigand, 2009; Koelsch, Gunter, Schröger, & Friederici, 2003; Koelsch, Rohrmeier, Torrecuso, & Jentschke, 2013; Korsakova-Kreyn & Dowling, 2014; Radchenko, Parin, Polevaya, Korsakova-Kreyn, & Fedotchev, 2014; Thompson & Cuddy, 1997; Tillmann, Bharucha, & Bigand, 2000), and the emergence of musical structure from tonal patterns (Krumhansl, 1996). The tonal relationships are routinely explained in musicology in terms of tension and stability (Fétis, 1844; Lerdahl, 2001; Riemann, 1877; Rosen, 1982; Schoenberg, 1954).

Since the 1980s, the *a priori* understanding that the perception of music is related to perceived tonal tension has been confirmed by empirical research that uses musical stimuli of various complexities, from individual tones of a scale (Krumhansl & Kessler, 1982) to brief harmonic progressions and fragments from musical compositions (Bigand, Parncutt, & Lerdahl, 1996; Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005; Krumhansl, 1996; Toiviainen & Krumhansl, 2003; Lehne, Rohrmeier, Gollmann, & Koelsch, 2013; Korsakova-Kreyn & Dowling, 2014). One of the important findings of empirical research in music perception was a link between perceived tonal tension and real physical tension (Nielsen, 1983; Madsen & Fredrickson, 1993; Williams, Fredrickson, & Atkinson, 2010). The empirical confirmation of this link brings music perception into the fold of embodied cognition, since, according to the concept of embodied cognition, the interaction between the motor system and sensory perceptions lays the foundations for the secondary and tertiary forms of human consciousness.

We will begin our discussion on embodied cognition in music with an explanation of the basic elements of music perception.

PERCEIVED TONAL TENSION AND MUSICAL SYSTEM OF REFERENCE

The theory of embodied cognition postulates that sensory information and motor activity are essential for understanding the surrounding world and for developing the abilities that are important for abstract reasoning (Foglia & Wilson, 2013). For example, because both memory and speech include sensorimotor representations, our imagination relies on previously experienced gestures and movements (Wellsby & Pexman, 2014). This is why people’s reactions to speech are faster when they see the physical movements described by the speech (Glenberg & Kaschak, 2002). The neuroimaging studies have shown that hearing a list of adjectives and verbs generates activation in the motor cortex for verbs only (James & Maouene, 2009), which demonstrates an association between speech and motor experience. Similarly, embodied cognition in music involves an association between melodic morphology and motor experience. This association is the main focus of the present paper.

Since this discussion resides within the confines of tonal music, it relies on the established body of theoretical works in the core musicology and on the wealth of empirical data obtained in those behavioral and imaging studies that employed the fundamental concepts of music theory. The discussion offers a revision of the current model of embodied cognition in music, which claims that apparent corporeal articulation plays an important role in music cognition. In contrast, the proposed model emphasizes the primacy of the tonal/temporal relationships which the music that people love to sing and dance to is made of. The lynchpin of the proposed model is the concept of perceived tonal tension, which is a principal concept for the core musicology (Lerdahl, 2001; Meyer, 1956; Schoenberg, 1954), for behavioral studies in music perception and cognition (Bigand et al., 1996; Firmino et al., 2009; Hevner, 1935; Korsakova-Kreyn & Dowling, 2014; Krumhansl, 1996, 1997; Toiviainen & Krumhansl, 2003; Thompson & Cuddy, 1997), and for the cognitive neuroscience of music (Bigand, Delbé, Poulin-Charronnat, Leman, & Tillmann, 2014; Foster & Zatorre, 2010; Koelsch et al., 2013; Radchenko et al., 2014; Tillmann et al., 2000).

The theoretical background for studies in embodied cognition in music often resembles the theoretical underpinnings of embodied cognition in language, when the apparent movements of music performers and listeners are emphasized as essential for understanding the music's content (Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2013; Krueger, 2014; Leman & Maes, 2014; Naveda & Leman, 2010) and for generating the sense of motion in music listeners (Clarke, 2005; Krueger, 2014; Reybrouck, 2005). Krueger (2014) connects music cognition to different forms of body movement, including tapping the fingers and nodding of the head. Likewise, Leman and Maes (2014) propose that "an intentional level of musical interaction is established through corporeal articulations and imitations of sensed physical information provided by the musical environment" (Leman & Maes, 2014, p. 236). However, the emphasis on the importance of apparent corporeal movement for determining intentionality in music contradicts the established dogmas in such music-related disciplines as (i) the music philosophy which explains the intentionality as a consequence of tonal expectations (Meyer, 1956; Scruton, 1997); (ii) analysis of musical forms, which elucidates musical reasoning and musical architectonics with the help of functional analysis and without any references to motor behavior of either musicians or music listeners

(Rosen, 1988; Hepokoski & Darcy, 2006); and, most important, (iii) the emphasis on importance of corporeal articulation for understanding musical meaning contradicts musical practice.

For example, we could perform an imagined experiment by asking a group of participants to report their affective responses to the main theme of the first movement of Mozart *Symphony in G minor* (KV 550) while observing the performing orchestra from a soundproof room. Then the same group could be asked to indicate their affective responses upon listening to the same musical theme but without *seeing* the performing musicians. According to Meyer (1956), the participants will be able to understand the musical meaning of the symphony when listening to it thanks to the *heard* experience of tonal expectations and their fulfillments and violations, whereas the visual information alone (*seeing* the playing musicians) will not be enough for music perception. The same imagined experiment could be applied to other kinds of pitched music (music endowed with tonal hierarchy), whether we listen to music for waltzes and anthems or this week's most popular song. However flamboyant or sober the appearance of a performing musician, the formation of a melodic image and its memorization by a listener rely, first of all, on the recognition of tonal/temporal patterns with which the image is encoded (Dowling & Harwood, 1986).

The tonal patterns spring from the tonal hierarchy. The simplest example of the tonal hierarchy is a musical scale (Figure 1). The seven tones of a diatonic scale present the hierarchy of tonal attraction towards a tonic, or a point of tonal stability. Figure 2 shows the results of Krumhansl and Kessler's (1982) study in the perception of a diatonic scale, where a tonic triad comprises the most stable tones of the scale, the diatonic steps I, III, and V. A tonic triad defines tonality (Fétis, 1844; Schoenberg, 1954).

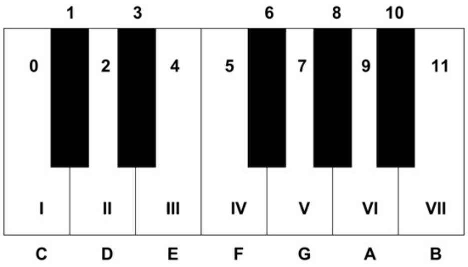

Figure 1: The C major scale comprises of seven diatonic steps indicated by Roman numerals. Arabic numerals indicate steps of a chromatic scale that begins on C

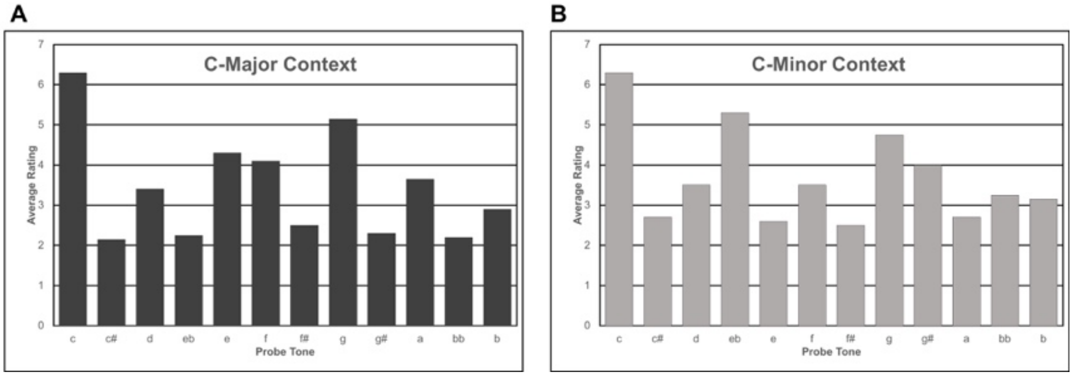

Figure 2: The tone-profiles: A. for the C-major scale and B. for the c minor scale (after Krumhansl & Kessler, 1982, p. 343, Fig. No 2. Tracing the dynamic changes in perceived tonal organization in a spatial map of musical keys. *Psychological Review, 89*, 334-368)

It is helpful to think about musical scale as a system of reference for the perception of melodies and harmonies. While our minds use visuospatial coordinates for perceiving the objects in the three-dimensional space, a musical scale allows for recognition of melodic objects in musical space. For example, when we hear the melody "Happy Birthday to You," our minds perceive the melody by navigating in a tonal space of a diatonic scale in a major mode.

A diatonic scale consists of seven diatonic and five chromatic tones. A reiteration of these twelve tones in different registers generates a musical diapason (for example, the notes of the 88 white and black keys of a grand piano). The distances between the first tone (tonic) and the other tones of a musical scale make 12 basic melodic intervals ranging from unison to octave. The intervals differ in the intensity of tonal instability in relation to the center of stability, the tonic. The same tones can be arranged in different melodies, depending on the order of tones along the arrow of time and depending on the relative time-value of tones. Together, a space of tonal relationships and the arrow of time constitute the tonal chronotope. (The concept of the literary chronotope was first developed by Mikhail Bakhtin [1937/1981] and then modified as the tonal chronotope in a study in melodic rotation [Korsakova-Kreyn, 2005, 2014]). When listening to music, we navigate the tonal space by following a particular tonal/temporal program.

While we hear individual musical sounds (and notate them) as "particles," each natural sound is made of a fundamental tone and a trail of softly sounding overtones, or an overtone series. The interaction among different overtone series defines the character of musical sounds. In general, those musical sounds that are perceived as tense are called dissonances, and musical sounds that are not perceived as tense are called consonances. The brain's patterns of activation for consonant and dissonant sounds differ for one-day-old babies (Virtala, Huotilainen Partanen, Fellman, & Tervaniemi, 2013), and two-month-olds demonstrate a preference for consonance (Trainor, 2004) (the sensations of musical dissonance and consonance are available to young chicks [Chiandetti & Vallortigara, 2011]). The data suggest that human beings are born equipped for perceiving a consonant-dissonant dichotomy and that the perception of consonant and dissonant melodic elements does not require high-order cognitive processing.

The consonant and dissonant qualia of combinations of musical sounds can be explained by differences in the amount of shared spectral information (see for review Bowling & Purves, 2015). For instance, the sonically pleasant Pythagorean intervals of an octave, a fifth and a fourth, all spring up in the beginning of any given overtone series (counting octave equivalence). When two notes belong to the beginning of the same overtone series – as this happens with the Pythagorean intervals – this produces a redundancy of important spectral information. The hypothesis of a gradient of the neuronal cost for auditory processing (Korsakova-Kreyn, 2005, 2010) proposes that this redundancy may create the conditions for more efficient processing of sound compounds and that this greater economy of effort at the level of neuronal nets may translate into a pleasant sensation known as musical consonance. This hypothesis corresponds to the "principle of least effort" (Ferrero, 1894). There is a supporting empirical evidence for the hypothesis. Research into neuronal activity in the brainstem in response to consonant and dissonant melodic compounds (Bidelman & Krishnan, 2009, 2011) reveals that the magnitude of brainstem frequency-following responses (FFRs) is more robust, and the responses are more coherent, for a consonant combination as compared to a dissonant combination. The strongest neural pitch salience is produced for unison, i.e., for two tones that have identical fundamental tones and overtone series. The obtained differences in magnitude of FFRs for triads show the gradient of perceptual consonance: major > minor > diminished > augmented (Figure 3).

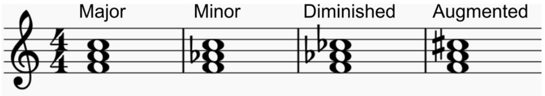

Figure 3: The magnitude of brainstem frequency-following responses (FFRs) for triads organizes as follows: major > minor > diminished > augmented (after Bidelman & Krishnan, 2011, p. 214, Fig. 2)

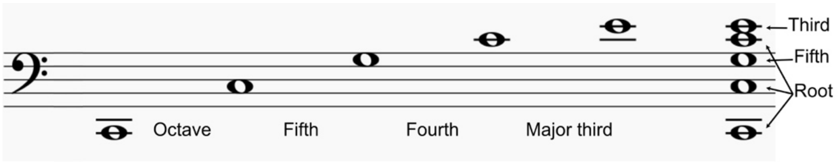

Figure 4: A triad in a major mode is made up of a fundamental tone and its four strongest harmonics at the very beginning of the overtone series for that tone

The Bidelman and Krishnan's studies make an important contribution to our understanding of the consonant-dissonant dichotomy. Most likely, the consonant compounds are sonically pleasing because they are easier to process; in comparison, the dissonant compounds sound tense because their processing requires more computational efforts from the auditory system. For example, a triad in a major mode is made up of a fundamental tone and its four strongest harmonics at the very beginning of the overtone series for that tone (Figure 4), which means that the tones of a major triad share important spectral information. The commonality of spectral information explains why a major triad produces a more robust FFR than other triads. These results elucidate the importance of the "hidden" dimension of overtones in music (people do not register consciously the overtone series). The interaction among different overtone series is also the source of a tonal force field that is defined as "phenomenal tonal gravity" (Scruton, 1997). In this force field, melodic structures appear as "folds" of a tonal space in the same sense that material objects are "folds" and "wrinkles" of a three-dimensional space (Florensky, 1925/1993).

Thus far, the explanation of consonant and dissonant sounds relied on the "hidden" dimension of overtones, foundational for musical proto-scale. Around 400 years ago, the purity of the overtone-based musical scale was violated, hesitantly, as musicians discovered a new and powerful means of musical expressiveness called tonal modulation, (i.e., the reorientation of a musical scale on a different tonal center within the same composition). Unimpeded use of tonal modulation demanded a systematically approximated tuning of keyboard instruments (Barbour, 1953; Schulter, 1998); in reward, tonal modulation stimulated the crystallization of the language of tonal harmony, which gave us polyphonic music and sonata form for clavier, symphonies for orchestra, and music for movies. Despite its tonal impurities, a tempered scale holds on to the precious functional characteristics of its diatonic steps (Jordan & Shepard, 1987). These functional characteristics are expressed by differences in perceived tonal tension.

The expression "tonal tension" belongs to a standard vocabulary for teaching music theory. The expression is helpful for explaining musical phrasing and for elucidating the details of thematic development in complex musical structures such as fugue (Walker, 2000) and sonata allegro form (Hepokoski & Darcy, 2006; Rosen, 1988). The empirical evidence for a possible link between perceived tonal tension and real physical tension (Nielsen, 1983; Madsen & Fredrickson, 1993; Williams et al., 2010) illuminates a connection between the tonal relationships, physical tension, and musical imagery, reaffirming the imperative role of the tonal relationships in generating “dynamic processes that are common in human experience” (Zbikowski, 2011, p. 187) in music. Among these dynamic processes is a feeling of musical motion, which arises from melodic intentionality inherent in tonal expectations (Lerdahl, 2001; Lerdahl & Krumhansl, 2007; Meyer, 1956; Schoenberg, 1954/1969; Scruton, 1997).

Music perception relies on the listeners’ ability to keep in mind the perceptual tonal schema (a musical scale) and to continuously compare each incoming sound with the tonic triad (Bigand et al., 2014; Koelsch et al, 2013; Korsakova-Kreyn & Dowling, 2014; Tillmann et al., 2000; Toiviainen & Krumhansl, 2003). Intuition for the tonal hierarchy allows to sense different regions of instability in a tonal space, and to expect a transition to tonal stability. In other words, tonal expectations generate melodic intentionality and a feeling of musical motion. Below is a more detailed discussion on the sensation of movement in music.

MOTION IN MUSIC

Figure 5 illustrates the perceptual basis for tonal patterns by showing, schematically, the unstable leading tone B gravitating towards the tonic C (see also Figure 2, after Krumhansl & Kessler, 1982). In a musical scale, a tonic is the most stable tone, while other tones of a scale differ in pitch and, most important, in the intensity of perceived gravitation towards a tonic. The interplay between various degrees of deviation from tonal stability lies at the heart of melodic intentionality.

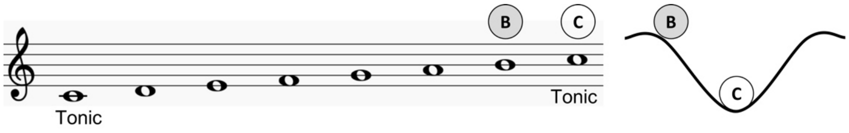

Figure 5: Musical scale is a system of reference where the tones differ in intensity of attraction toward tonal center (tonic). For example, the leading tone B gravitates (has potential tonal energy) to a tonic C in the C major scale

The process of perception and integration of the unfolding tonal patterns into melodic image arrives to our minds as (e)motion (melodic motion and affective image, or virtual emotion). Here is an example of Chopin' *Etude in C Major,* op. 10, No 1 (Figure 6). The musical score shows a rhythmically monotonous pattern of sixteenth notes in a treble clef and a relatively regular pattern of the whole notes and half notes in a bass clef. An attempt at corporeal articulation of the *Etude* by a naïve listener could result in regular movements either rightward—leftward (the linear direction of the musical passages on a piano keyboard) or up and down (the melodic direction frequency-wise). In reality, the passages of the *Etude* are filled with minute tonal changes and with refined sensitivity that is characteristic for Chopin's harmonies, such as a transition that begins in a measure 5 and makes the following harmonic progression: the dominant (G major), the double dominant (D major seventh), a seventh chord with a lowered sixth (A-flat) on a supertonic accompanied with a sustained bass on the dominant tone G, the dominant chord (G major seventh) with a passing D-sharp on a last quarter of this measure, which leads to the E (a third of the C major tonic triad). The passing D-sharp (in measure eight) adds intensity to an image of a swift and exuberant movement (imagine a youthful and intrepid winged victory). The added intensity of the D-sharp illustrates how tonal patterns convey the musical intentionality. Specifically, a music listener expects the D-sharp (an unstable passing note) to resolve into a tone E, a stable step III in a tonic triad in C major. Here the tonal expectations equate with the melodic intentionality that creates a feeling of melodic motion. There are other musical aspects that help creating a feeling of airy openness and transcendence in the Etude, such as a juxtaposition of a slow movement of deep bass notes and the soaring swift motion up and down in the middle and high register of a piano.

In the absence of sound, neither a gestural interpretation of the music, nor a video recording of the musician's hands making passes over a piano keyboard could convey the powerful sense of melodic motion and the depth and intensity of musical emotion encoded in the tonal/temporal patterns of the *Etude*.

Figure 6: Fragment form *Etude in C Major*, op. 10, No 1 by Frederick Chopin (Public Domain: http://ks.imslp.net/files/imglnks/usimg/7/71/IMSLP367492-PMLP01969-Chopin_Etudes_op.10_-_Cortot_(french).pdf)

A different point of view proposes that motion in music is principally related to music's temporal organization and that some sound effects, such as changing the location of the sound source in relation to the listener or an increase and decrease in the volume of sound (*crescendo* and *diminuendo*) could be the causes of perceived motion in music (Clarke, 2001). The latter suggestion alludes to Roman Jakobson's idea of the motor aspect of a linguistic sound (Jakobson, 1978). And yet, Jakobson was very clear about the contribution of the elemental components of speech production to the meaning of speech. He wrote, "[T]he phoneme, although it is an element at the service of meaning, is itself devoid of meaning" (Jakobson,1978, p. 109). Similarly, although a given musical sound is an element at the service of meaning in music, the sound is devoid of musical meaning in the absence of the tonal relationships. For example, we could listen to the first note of the *Etude* (Figure 6), the note C, from different corners of a room or we could modulate the loudness of C, but neither of these two operations would produce a sense of musical movement – because an isolated note C does not afford melodic intentionality. Music needs interaction among different melodic elements (the "relational thinking" [Riemann, 1877]) to create musical meaning. As for the proposal that movement in music is generated primarily by metrical/rhythmical organization, such a proposal implies that the notation of a melody in terms of only time values would be enough to encode musical motion in the melody. Figure 7 shows four rhythmical units, where the units 1, 2, and 4 are identical. One could react to the rhythm with corporeal articulation, but it is hard to see the unique markers for musical motion in the rhythmical pattern.

Figure 7: Four rhythmical units that are alike with an exception of a unit 3 that includes two quarter notes instead of a half note

Everything changes when the same rhythm appears in pitch notation (Figure 8), which reveals a melody of "Happy Birthday to You." The melody expands from C by reaching up a perfect fourth in the first rhythmical unit, a perfect fifth in the second unit, and an octave in the third unit. From this high point the melody changes its direction and descends, over the tones of an F major triad (a tonic triad) and the passing tone E, to a tone D. From the D, the melody reaches up to a B-flat and then concludes with authentic cadence, A, F, G, and F. (In Western music theory, a cadence is a concluding of a musical phrase. In authentic cadence the dominant chord resolves into a tonic triad [Schoenberg, 1954/1969]). The sense of musical motion in the tune is afforded by the tonal patterns made of the stable and unstable tones and by melodic direction that involves the increase in the size of melodic intervals (a second, a third, a fourth, a fifth, and an octave). The perception of tones in the tune is enriched by the implied harmonization (Holleran, Jones, & Butler, 1995). For example, in the first rhythmical unit, the leading tone E implies a chord on the dominant, which leads our tonal expectations to a resolution on a tonic F in the second unit. The implied harmonization relies on the same gradient of tonal attraction that generates the tonal hierarchy of a musical scale.

Figure 8: Melody of “Happy Birthday to You” in pitch notation (Public Domain: https://www.snopes.com/2015/09/22/happy-birthday-public-domain/)

The foundations of implied harmonization manifest in the four opening measures of the *Prelude in C major*, WTC I, by J. S. Bach (see Figure 9). Each of the measures presents a single broken chord played by sixteen notes in a wave-like way. The four beginning measures make the following progression of chords: a C major triad, an inversed seventh chord on supertonic, an inversed G major seventh chord, and the C major triad. This brief harmonic progression represents the fundamentals of the language of tonal harmony: Tonic (I) - Subdominant (IV) - Dominant (V) - Tonic (I). The first measure establishes a system of reference, which in this case is a scale in a major mode with the tonic C. The second measure creates a sense of a mild instability with a seventh chord that belongs to a subdominant sphere. The third measure includes a leading tone (in the inversed dominant seventh chord), which generates a sense of instability and an expectation of melodic motion towards stability. The expectation is fulfilled in the fourth measure when the musical phrase concludes on a C major tonic triad.

Figure 9: Fragment from *Prelude in C major*, WTC I, by J. S. Bach. The first four measures establish a *formula of tonal motion:* Tonic (I), Subdominant (IV), Dominant (V), and Tonic (I) (Public Domain: http://ks.imslp.net/files/imglnks/usimg/0/0e/IMSLP224382-PMLP05948-Bach_JS_CBT_I_Prelude_1_BWV846.pdf)

The four beginning measures of the *Prelud*e reveal the succinct *formula of tonal motion*, which rules over our tonal expectations and underlies both phrasing and a sense of motion in music. Tonal expectations are the engine of melodic intentionality. The process of musical motion is encoded in the *Prelude* by means of the artful sequencing of tones in time. While a physical motion of a pianist is needed to convey melodic motion, these two kinds of motion—physical and melodic—cannot be equated because music involves more than just kinesthetic information and because physical performance of music by a musician is a consequence of melodic thinking and not vice versa. To elucidate the concept of melodic thinking, we will examine the phenomenology of melodic structures in the next section.

MELODIC OBJECTHOOD

In his discussion on meaning in music, Scruton (1997) identifies two auditory domains – acoustic and acousmatic, the former serving as the material foundation for the latter. In the domain of acoustics, a given sound can be explained with numbers in term of frequency, duration, amplitude, and prominence of specific harmonics in a spectral envelope. In the acousmatic domain, humans listen to musical structures shaped by the tonal/temporal relationships: here, in the acousmatic domain, the physical qualia of sound acquire their musical meaning by becoming part of melodic thought. The timbre, register, duration, and variation in the volume of a musical sound can be analyzed in terms of physics, but the acoustical characteristics of musical sounds are artistically meaningless outside melodic thinking that relies on the two principal and interwoven dimensions of music – a space of the tonal relationships and the arrow of time. The artistically arranged tonal/temporal relationships allow for transducing sound events into a musical structure infused with emotion.

A differing opinion holds that "features of a musical piece heard as a sonic world are shaped by the environment in which the piece is experienced. In other terms, music listening is always embedded …" (Krueger, 2011a, p. 7). This statement mixes two phenomena: the primary process of shaping a musical piece by the tonal/temporal relationships ("features of music") and the tertiary phenomenon of various environmental influences affecting the listener's response to the already shaped music. It is not the "embeddedness" into the environment, which accomplishes musical Gestalt; this kind of "embeddedness" can be easily divorced from music without damaging the music's intrinsic content. For instance, when "Happy Birthday to You" is played by different instruments or sung by different voices in different contexts or spaces (whether a living room or a grassy lawn), the listeners are still able to recognize the familiar tune. The primary forces of the tonal relationships are so strong that a melody could be divided between different musical instruments (the technique of *Klangfarbenmelodie*, Schoenberg, 1911) or between a musical instrument and a voice and still be perceived as a unified melodic object. Thus a mother could start a nursery tune on a piano and her small child would happily sing the tune to completion—and they both would feel that they made a single melody together.

We sense a familiar melody as a whole (as having a beginning and an end) precisely because the melody is not just the sum of acoustical events but a unified object that transcends a set of elements comprising it. The elements acquire their meaning in relation to the whole. It is the entirety of melodic structure that dictates the appropriateness of the specific acoustic features of the constituent musical sounds, whether relative sound volume or slight variations in duration dictated by expressive timing. This explanation is radically different from the definition of music as a "collection of vibrational events" (Reybrook, 2015), because the latter definition does not go beyond acoustics.

The defining role of phenomenal tonal gravity for musical morphology explains why the physical environment of listening is not essential for identifying a familiar melody. Even a tempo and some variations in rhythm could defer to the tonal relationships so that a slow and expressive singing of "Happy Birthday, Mister President" by Marilyn Monroe (Monroe, 1962) and a choppy playing of the same tune by a young beginner student do not hinder the recognition of the tune. Actually, we are able to recognize a familiar melody in about 3 seconds by listening to just a few beginning notes (Dalla Bella, Peretz, & Aronoff, 2003). It was found that when pregnant mothers listened daily to the same melodies (a different melody for each mother) during last weeks of full-term pregnancy, their newborns were able to recognize "their" melodies (Granier-Deferre, Bassereau, Ribeiro, Jacquet, & Decasper, 2011). This means that the babies remembered the musical objects made of specific sequences of tones, and not just the sets of sound events.

It is possible that integration of musical elements into melodic objects in acousmatic domain involves supramodal processing. In his model of the functional hierarchy of the brain, Alexander Luria (1973) proposes that the secondary and tertiary cortical zones of the brain perform an integrative role "which is necessary for more complex gnostic processes" that are progressively less modality-specific (Luria, 1973, p. 77). His model offers neuropsychological ground for the concept of acousmatic space and for the explanation of melodic transformation as an attribute of quasispatial reasoning in music (Korsakova-Kreyn, 2005, 2014; Korsakova-Kreyn & Dowling, under review). Philosophically, the hypothesis of supramodal processing in music perception suggests that the brain translates auditory information into the legible musical images by detecting a configuration of relationships among heterogeneous melodic elements in the context of phenomenal tonal gravity.

Scruton explains musical structures as the societies of tones united by the interrelationships: a "tone is heard as the response to its predecessor, as tending towards its successor, as continuity in action which makes sense as a whole" (Scruton, 1997, p.76). The artful sequencing of musical sounds is capable to convey the process of feeling or, in the words of Susanne Langer (1942), music is able to recreate the *logic of emotion*. While the visual arts present us with the psychological states (for example, the state of profound sorrow in Michelangelo's *Pieta*), music leads listeners through the process of forming the sound images of time. A given musical composition, as a particular arrangement of tonal/temporal relationships, creates a particular image of psychological time, or emotion. Music generates aesthetic emotion that includes the sense of beauty (Florensky, 1925), cultural constructs (Stevens, 2012), nonpragmatic interests (Scherer & Zentner, 2008), and the idiosyncrasies of personality and memories (Minsky, 1981; Vuoskoski & Eerola, 2011).

The influence of music on the psychological states of the listeners occurs in the absence of either the prompting words or visual imagery able to activate basic emotions (Pribram, 1960). Instead, the complex state of aesthetic emotion emerges in response to artistically sequenced tonal relationships that generate "vague intuitions and introspective sensations" (Ives, 1920, p. 7). The statement, "auditory properties of the produced sound (tempo, intensity, volume, etc.) coax specific emotional responses out of the listeners" (Krueger & Szanto, 2016, p. 876) misses the principal mechanisms of endowing the sounds with musical meaning, namely, the tonal relationship. When the "auditory properties" are not in agreement with the logic of a musical image that is encoded in the tonal/temporal patterns, the listeners are subjected to a non-musical experience.

Neglecting the main principle of melodic morphology leads to confusion around the concept of spatiality in music. For example, Krueger (2011b) proposes two forms of musical spatiality: "inner" and "outer" musical spaces, which he differentiates by the degree of attention allotted to musical sounds by a listener. Krueger concludes that "the locational spatial character of a musical piece remains experientially prioritized" during a passive hearing of music (Krueger, 2011b, p. 71). It is not clear what properties generate the "locational spatial character" of music. According to musicological dictum, formation of musical structures involves, first of all, the pitch space and arrow of time. The physical location of a listener does not belong to melodic morphology – this is why a musical composition (a tonal time-space of a specific configuration) remains the same whether the listener hears the composition in a crowded concert hall or in a privacy of his bedroom. Krueger writes about the attentive listener, "[A]s this listening becomes intensified and further focalized … another region of inner space becomes phenomenally accessible: the space of musical relationships" (Krueger, 2011b, p. 73, fn. 7). This statement implies that musical relationships are not available until the listener reaches a sufficient level of attentiveness. If this were true, there would be no commercial interest in musak. Whether listening to music attentively or not, people recognize music by sensing musical relationships, spontaneously and intuitively. There is an exception. When studying musical architectonics and the nuances of voice leading and harmonic development, professional musicians do apply focalized attention to musical relationships by employing the structural analysis of musical form and functional analysis of tonal harmony. Otherwise, listening to music is an intuitive process of navigating in a stream of musical sounds (Bigand et al., 2014; Toiviainen & Krumhansl, 2003).

When Chemero writes, "[M]uch work in radical embodied cognitive science explores what is often called minimally cognitive behavior, such as categorical perception, coordination, locomotion, and the like" (Chemero, p. 39), he catalogues the main properties of the tonal chronotope, such as coordination (navigation) in the tonal field and the phenomenal locomotion, or a sense of action generated by melodic intentionality. Music has its own rules that create the space of melodic thinking: This space is the musical environment in its own right.

The emphasis on the interwoven tonal and temporal aspects of music perception exemplifies the main thrust of the presented two-level model of embodied cognition in music. Next we will discuss the intrinsic musical causes of the apparent motor behavior of music performers and music listeners.

APPARENT CORPOREAL MOVEMENT AND MUSIC COGNITION

Studies in embodied cognition in music often focus on apparent bodily movement during music production and perception (Burger et al., 2013; Clarke, 2005; Davidson, 2007; Krueger, 2014; Leman, Desmet, Styns, Noorden, & Moelants, 2009; Leman & Maes, 2014; Naveda & Leman, 2010; McGuiness & Overy, 2011; Reybrouck, 2005; Schiavio, Menin, & Jakub, 2014). However, an explanation of embodied cognition in music from the perspective of kinesthetic information misses the musical causes of apparent motor behavior of musicians and listeners. For example, the effect of musical phrasing on corporeal movement has its source in tonal functions (see commentary for Figure 9).

Music perception is akin to navigation in a force field and, in the cases of polyphonic music and thematic development in sonata allegro form, music perception involves quasispatial reasoning. The results of studies in the perception of melodic contour (Dowling, 1972, 1973; Foster & Zatorre, 2010; Korsakova-Kreyn, 2005, 2014) support the concept of a melody as a melodic object that is available to perception even when it is transformed in ways that resemble visuospatial transformation (Shepard & Cooper, 1982). Thematic development in a classical sonata and in traditional polyphony relies on people's abilities to sense a melody as a unified object in a tonal time-space where a melody could be "augmented" and "diminished" in time, as well as "bent" by tonal forces. The division of sound time in polyphonic compositions alludes to the division of the plane in Escher's tessellations (Escher himself noted the similarity [in "M. C. Escher," 1983, p. 32]).

While a melodic contour, as a combination of ups and downs in pitch, can be easily illustrated with a gesture, a gesture cannot convey the tonal relationships that encode and communicate musical meaning. The problem of connecting observable gestures to musical content emerges as soon as we try to compare ordinary visuospatial perception, which takes place in the three-dimensional world, with melodic and harmonic reasoning, which takes place in cyclical tonal space (the 12-tone space has its explanation in a toroidal model [Purwins, 2005; Purwins, Blankertz, & Obermayer, 2007]). Even melodic direction, which is the easiest aspect of music to illustrate with a gesture, has different affective influence depending on the tonal context (Korsakova-Kreyn & Dowling, 2014); namely, a melodic direction exerts affective influence in the case of a musical phrase that modulates to a nearby key but not in the case of modulation to a distant key.

Pedagogical practice does employ gestures for illustrating expressive timing, dynamics, melodic direction, and to indicate the rounding of a musical phrase. Yet overall, neither music pedagogy nor performing practice sees corporeal articulation as playing a significant role in expressing the content of music in musical performance. As any professional musician knows, a deeply expressive performance can be visually modest (not to mention that when we listen to the recordings of musical performances, there is no visual information about the process of performing). Such outstanding musicians as Sviatoslav Richter and Glenn Gould believed that watching a pianist performing music distracts from listening to the music and from understanding its meaning. A study by Tsay (2013) found that visual information could override the subtleties of musical information when people judge music performance during a competition.

To explain the formation of musical meaning, the ecological theory of embodied cognition in music (Clarke, 2005; Godøy & Leman, 2010; Krueger, 2014; Maes, Leman, Palmer, & Wanderley, 2014; Reybrouck, 2015) incorporates Gibsonian ideas that were originally developed for visual perception (Gibson, 1979/1986). Among its key ideas, the ecological theory employs the concept of affordances. Gibson's concept of affordances states that the perception of the environment affords possibilities for movement and action. When Gibsonian ideas are applied to music on the "surface" level of apparent corporeal articulation, the theoretical framework of embodied cognition in music becomes focused on the apparent corporal reactions to the rhythmic regularities in music (Krueger, 2014; Leman, 2010, 2012; Maes et al. 2014) and on the commonly accepted notion that music generates subjective emotional responses influenced by personal idiosyncrasies (Reybrouck, 2015) and by environmental factors (Krueger, 2011a; Krueger & Szanto, 2016). Reybrouck writes, "[I]t is possible to conceive of the process of dealing with music in ecological terms as "coping with the sounds." This means that the way that listeners make sense of music is determined both by the characteristics of the listener as an organism and the music as environment" (Reybrouck, 2015, p. 14). Reybrouck thus formulates an all-embracing approach to making sense of music by a listener, which reflects the reality of music perception in a general sense. But this approach is not feasible for elucidating *how* musical meaning is generated and *what* specific musical means support the emergence of musical meaning.

There is another problem: By imposing the equal-opportunity principle on non-equal parameters (and by including among the parameters the multitude of possible environmental influences on music listener, as well as his/her neuropsychological characteristics), the approach homogenizes the influences and thus minimizes the role of musicological and scientific scholarships in the discourse on musical meaning. By creating a potentially limitless continuum of environmental criteria – and by equalizing the influence of tonality and rhythm on music perception with the influence of diverse environmental happenings – the "surface-level" ecological theory of music makes a conceptual twin of stochastic music (Xenakis, 1963). Whereas stochastic music uses sophisticated mathematical tools and can produce beautiful sonic effects, the lack of a perceptual schema (such as the perceptual hierarchy in tonal music) limits the degrees of freedom for melodic thought, and thus for expressing the human condition in stochastic music.

In comparison, when Gibsonian ideas are employed on the "deep" level of embodied cognition in music, they become a powerful instrument for furthering our understanding of the formation of musical meaning. To simplify the explanation, let us compare music perception with the perception of visual objects that are apparently suggestive of their possible usefulness, harmfulness, pleasantness, ugliness and so forth. Unlike the material objects, music is a non-representational auditory art that carries, intrinsically, both movement and action in the melodic intentionality afforded by phenomenal tonal gravity. The suggestiveness of music is not semantically bound since musical syntax has no cognitive constants such as words or recognizable visual images. Although spatial metaphors permeate the analysis of musical structures, images of music dwell in the acousmatic space where tonal patterns express psychological time.

Here we propose that Gibsonian ideas apply effectively to the theory of embodied music cognition on the "deep" level of tonal expectations, melodic intentionality and thematic development, which all rely on the affordances of the tonal relationships and expressive timing. For example, comments for Figure 6 explain how the deviations from tonal stability generate melodic intentionality that translates into a sense of motion in music. Gibson writes, "perceiving is a registering of certain definite dimensions of invariance in the stimulus flux together with definite parameters of disturbance" (Gibson, 1979, p. 249). Congruently, in music, movement and action are generated through the artfully sequenced deviations of the variant melodic elements from the points of tonal stability afforded by the certainty of perceptual tonal schema. Tonal fluctuations – deviations from and restorations to stability – create images of musical motion by generating tonal expectations that translate into melodic intentionality. The phenomenal musical motion is intrinsic to virtual reality of musical emotions.

Melodic thinking dwells in the acousmatic domain where the auditory information becomes interpreted and integrated with the help of a perceptual schema (musical scale). It is only after the process of integration of tonal/temporal information takes its course that other aspects of music cognition—the personal idiosyncrasies, memories, and specific circumstances—enter the acousmatic domain. First we need to recognize the music and only then our perception of the music becomes enveloped into the many layers of subjective experiences.

GESTURES AND EXPRESSIVENESS IN MUSIC

There is a special case in music performance when corporeal articulation is thoughtfully studied and practiced with an eye to achieving technical virtuosity of execution. The art of conducting is defined by the expressiveness and precision of gestures whose purpose is to assist a group of musicians in realizing the shared goal of conveying the content and structure of a musical composition. A conductor's gestures take into consideration the specifics of different musical instruments, such as brass versus string instruments, and of the voice. These gestures are suggestive of the character of the music in relation to the phrasing, variations in sound volume, melodic direction, tempo and rhythm, and accentuation and grouping. All these aspects of conducting are dictated, first of all, by the logic of a melodic thought that is made up of tonal relationships unfolding in time. For example, the opening theme of Shostakovich' *Fifth Symphony* makes a dramatic leap up and then a dramatic leap down, and yet the conductor Dudamel (Dudamel, 2010, 0:08-0:20) does not lift his arms with the first leap up on a minor sixth and he does not lower his arms when the orchestra plays a minor sixth down. The conductor's apparent movements are not related to the melodic direction at all. Instead, his movements are related to the tragic mood of the music and to the technical problem of bringing the strings together on the difficult thirty-seconds of the sharply dotted rhythm that contributes to the dramatic exertion that characterizes the opening theme.

If a musician's gestures appear meaningful to the listeners, this is so because these gestures follow the program of musical intentions encoded in the tonal/temporal patterns of tonal tension and release from tension. For example, when, during the rounding of a musical phrase, a pianist slows down the music's pace and, on touching the final chord, makes a visible transition from being physically tense to becoming physically relaxed, the causes of the observable transformation reside in the details of the tonal/temporal relationships that dictate the psychomotor program.

Musical performance does demand physical effort and bodily movement, and skillful playing of a musical instrument can give tremendous pleasure to a performing musician, but this pleasure is inseparable from the precision of playing the musical notes. When a musician makes a mistake, this can be devastating for the musical content of the composition – even if the apparent corporeal articulation looks about the same for the wrong notes and the right notes.

An astute critique of the idea of corporeal articulation informing the meaning of music came from the pioneers in the field of embodied cognition, Frances and Bruchon-Schweitzer, who wrote, "[E]xpressive distinctions are easily encoded by the listeners through the verbal labels, but they are practically untranslatable by bodily mediation, when body expression is induced by the musical stimulus"

(Frances & Bruchon-Schweitzer, 1983, p. 594). As an exercise, the reader may try to corporeally express Beethoven's *Moonlight Sonata* (Op. 27, No. 2) without touching a piano, in silence, and to evaluate how the apparent bodily movements alone will be able to convey the subtleties of melodic thinking in any of the three movements of the *Sonata.*

To examine the hierarchy of relationships between music (the auditory art) and apparent bodily movement, a perception of which relies on visual processing, we are turning our attention to an established art form that combines music and expressive movements of the whole body.

APPARENT CORPOREAL ARTICULATION AND MULTISENSORY INTEGRATION

As a novel development in cognitive science, the field of embodied cognition in music has been undergoing a process of clarification of criteria. Leman's concept of the "human body as mediator in a musical meaning formation process" (Leman 2010, p. 43) is eminently useful in the field of music cognition. However, we need to be more specific in identifying what exactly makes the human body the mediator for musical meaning. The strongest argument for the "surface" level of embodied cognition in music comes from studies in the synchronization of people's movements in response to meter and rhythm (Burger et al., 2013; Maes et al, 2014; Naveda & Leman, 2009; Platz & Kopiez, 2012; Su, 2016). Music has been used for millennia for accompanying important ceremonies and for dancing and marching (Clarke, DeNora, & Vuoskoski, 2015). The repetitiveness of musical meter makes it easier for a group of people to move together (Repp & Su, 2013). The power of repetitiveness is so great that synchronized movement can be elicited without any melody (Codrons, Bernardi, Vandoni, & Bernardi, 2014). (Large & Gray [2015] showed that rhythmic entrainment could be elicited from nonhuman primates.) Even for an art form as music-oriented as ballet, music is often considered a mere provider of a musical meter (Martens, 1918).

Contemporary ballet, that integrates modern dance and classical ballet, offers illuminating evidence for the relationship between music and corporeal articulation. For example, the innovative works of choreographers Jiří Kylián and Nacho Duato Bárcia illustrate musical content by using the expressive movements of the whole body. These corporeal movements are created in response to musical ideas. It is important to keep in mind that the musical ideas are formed by specific musical means and that the corporeal movements, designed by the choreographers, strive to illustrate and interpret the music's content. Likewise, those investigations that either videotape or use optical motion-capture systems to study how people move with music (Burger et al., 2013; Su, 2016) address the gestural (secondary) interpretations of emotional (primary) responses to music – these emotional responses are elicited by the *musical* means. Calling the corporeal articulation an intermediary for formation of musical content smacks of a variation on a "cargo cult" (Worsley, 2009), in which surface features (the shape of the plane) are taken as the cause of the goodies it brings. Music can do without an interpreter. When Duato's choreography shows an interaction of a man (Musician) and a woman (Cello), the scenery does not create the musical content of the *Prelude* from Bach *Cello Suite No.1 in G* but serves as a visual illustration to Duato's feelings about the music (Duato, 2012). Take away the sounds of music, and the scenery loses its particular musical meaning, for gestures alone are not able to convey the nuances of melodic thought.

Here we suggest that research in the effects of visible corporeal movement on understanding the meaning of music actually belongs to research in the multidisciplinary performing art forms, such as opera, pop-music stage production, dance, and the like. In general terms, the visual component of musical performance belongs to the interpretation of music, that is, the visual component is not independent from the main morphological aspects of music. It is the tonal/temporal program of a given musical composition that dictates the physical communication of the composition by a performer. The visual component can influence music listeners (Tsay, 2013), yet this influence does not validate the statement, "there is no justification for the separation of modalities" (Platz & Kopiez, 2012. p. 71) – unless this statement refers to the multidisciplinary performing art and not the meaning of music. In reality, visual and auditory modalities are easily separated in music perception. For example, when we want to perceive the latest top song or a favorite string quartet, we could use the headphones. Moreover, music identification systems (for example, Shazam) rely on auditory information only.

Regardless of the complexity of musical content, music perception is guided by tonal expectations that generate a sense of melodic motion and musical structures (such as a musical phrase). Formation of musical structures that convey musical content involves the rules of musical syntax. We will discuss these rules in the next section.

SYNTAX IN MUSIC AND TONAL GOALS

People use semantic units (words) to describe things and actions. In music, there are neither words nor familiar visual images and, unlike the language of mathematics and a foreign tongue, music cognition does not require special training (Bigand et al., 2005; Bigand & Poulin-Charronnat, 2006; Fritz, Jentschke, Gosselin, Sammler, Peretz et al., 2009). There is a shared primeval root for music and speech, which is vocal production (the first signaling system [Pavlov, 1932]). The evolutionary bifurcation of vocal production led to formation of two different kinds of communication: speech and music. Speech provides high-level precision in the transfer of information: It operates using semantic units representing actions, things, phenomena, and qualia. In contrast, music dwells on the emotional component of vocal production: Music operates using musical sounds organized hierarchically. The conventional syntax of music is expressed in a succinct formula of tonal harmony made up of a sequence of four chords: a triad on a tonic (I), a triad on the subdominant tone (IV), a seventh chord on the dominant tone (V), and the concluding tonic triad (I). The majority of the music we hear today on headphones, during parties, and in the concert halls relies on this formula. Empirical studies have demonstrated that people have an innate understanding of tonal harmony and that listeners apply the rules of tonal harmony even when listening to a solo melody (Holleran et al., 1995).

Music is a process. A tonal system of reference (musical scale) provides the framework for generating a sense of musical intentionality, or a sense of motion, suspense, uncertainty, resolution, and so forth. Whereas the process of the unfolding of emotion in music involves navigation in a tonal space, the concepts of "goal-directed tonal movement" (Krueger, 2014) and "local goals or musical target notes in a context of surrounding supporting notes" (Leman & Maes, 2014, p. 238) are inapplicable to the art of music. To suggest that music has tonal goals and target notes is to suggest that Spinoza wrote his "Ethics" by following the goals of linguistic syntax and not the higher goals of formulating profound truths. Tonal syntax is a vehicle for the formation of the virtual space of musical emotions and general ideas (such as the "Fate motif" in Beethoven's *Fifth Symphony*). In other words, the principal formula of syntactic rules in music makes the scaffolding for tonal structures; neither of the constituents of this formula can be explained as a tonal goal of musical development.

A pitch space of music (Lerdahl, 2001) provides a medium for melodic thought, where complex interactions between tones (Bigand et al, 2014) are perceived intuitively and unfold in time into a musical image. The formation of musical image relies on a "stimulus flux" (Gibson, 1979), i.e., oscillations around points of tonal stability, which are determined by the hierarchical organization of tonal functions. A performing musician plays with sound-time of music by balancing the tonal masses of a musical structure in such a way that a musically encoded message emerges full force. The process of shaping a musical image involves both the bird's-eye view of the global musical architectonics and a detailed attention to the volume, timbre, and expressive timing. The attention to the details is guided by a sense of overall musical structure. For example, a virtuoso passage does not have a tonal goal but all its notes need to be played with precision and in agreement with the logic of a musical image. This logic dictates the variations in volume, the specifics of articulation, and expressive timing (*agogic* and *rubato*).

Whereas there are no tonal goals and targets in real music, there are tonal targets in musical stimuli that are used for research in the perception of tonal syntax. The ideas of the research originate in musical practice. For example, some tonal modulations are typical for classical sonata form (Hepokoski & Darcy, 2006; Rosen, 1988; Schoenberg, 1954), while certain interrupted cadences are popular as the pleasant surprises. Figure 9 shows an example of a popular modulation to the dominant step in Bach *Prelude in C major*, WTC I (measures 5-10), and Figure 10 shows an example of an interrupted cadence to an ascending sixth in Schubert' *Piano Sonata in A major* (D664) (measures 22-26). Neither modulation has a tonal target here, but both are part of melodic/harmonic development carrying the logic of complex human emotion and reflecting on the rational agency that permeates the great musical compositions. Thus the interrupted cadence in Shubert' *Sonata* (Figure 10) comes as a touching moment of respite from a melancholic longing of the previous measures.

Figure 10: Fragment from a second movement of *Sonata in A major* (D664) by Franz Schubert. The unprepared modulation to a diatonic step VI (from F-sharp minor to D major) represents a pleasant-surprise modulation of pseudostability kind (Public Domain:

http://imslp.eu/files/imglnks/euimg/2/2c/IMSLP374197-PMLP02034-Schubert_-_Sonata_in_A_major,_D._664_(Henle).pdf)

In contrast, the concept of a tonal target is routinely used in the studies in tonal syntax, which explore the effect of tonal distance on the perception of reorientation in a tonal space. Figure 11 shows an example of musical stimuli for an EEG study in tonal modulation, where the stimuli are differentiated according to the proximity of the target steps. The stimuli are intentionally musically impoverished to control confounds. Technically, the magic of musical thought in Schubert's sonata (Figure 10) can be described as unprepared modulation to a diatonic step VI, representing a pleasant-surprise modulation (Korsakova-Kreyn & Dowling, 2014). The "surprise" means here that at the moment of transition to a diatonic step VI, the flow of music deviates from the tonal expectations dictated by the tonal system of reference. By artfully violating and fulfilling the listeners' expectations, Schubert's music shapes our psychological states with the fluid images of virtual emotional reality. The tonal system of reference does not provide goals but affords a supporting frame for melodic thinking.

Figure 11: Harmonic progression with four different target steps: 1. zero-step; 2. the subdominant step; 3. a lowered ascending sixth; 4. a tritone

The basic formula of tonal harmony (the harmonic progression on diatonic steps I–IV–V–I) also represents an authentic cadence that underlies melodic phrasing. For instance, while we intuitively feel the conclusion of the melodic phrase at the end of "Happy Birthday to You," this feeling has a theoretical explanation – the arrival to a home-tonality via authentic cadence V-I (Dominant-Tonic). The syntactic system of tonal harmony in Western music "is rooted in the psychoacoustic properties of sound" (Bigand et al., 2014, p. 1). These psychoacoustic properties are related primarily to the interaction among different overtone series, which means that the psychoacoustic properties of melodic elements are born at the intersection of the physics of sound and the neurophysiology of human hearing. This trivial statement intends to emphasize the inborn sensitivity of humans to the basic melodic elements. During childhood, the flexible sensitivity to melodic hierarchy (Jordan & Shepard, 1987) develops spontaneously into an intuition for functional harmony (Bigand & Poulin-Charronnat, 2006; Costa-Giomi, 2003). The intuition underlies the ability to sense musical structures. The next section discusses the relationships between the intuition for functional harmony and psychomotor behavior, including the proprioceptive experience and corporeal articulation.

MUSICAL MEANING AND PROPRIOCEPTION

The word "proprioception" was introduced by Sherrington (Sherrington, 1906). Proprioception is defined as a "sense or perception, usually at a subconscious level, of the movements and position of the body and especially its limbs, independent of vision" (Farlex Partner Medical Dictionary, 2012). Musicians dedicate years of focused practice to honing their performing technique, including their motor skills. As a result, some elements of musical performance become controlled intuitively, whether during playing the virtuoso passages or adjusting a "touch" (sound volume and articulation) to the acoustics of an unfamiliar concert hall. The complexity of playing technically difficult compositions, such as Bach *Partitas* for a violin and Chopin *Ballades* for a piano, precludes a conscious regulation of each movement of the shoulders, arms, hands, and fingers during a musical performance. Instead, when the imagery of a musical composition ripens and becomes technically internalized, a performing musician feels that musical images appear as if shaped by hands – as if the proprioceptive program itself generates music and proprioception is the "basis" for feelings in music (Peñalba, 2012).

There is a problem, however, that makes it difficult to accept the idea that a proprioceptive program could be the basis for the meaning in music. This problem is illustrated in Figure 12, showing three versions of the tune “Mary Had a Little Lamb.” Each version is played on white keys only in order to preserve a proprioceptive program. In the first version, “Mary Had a Little Lamb” begins on E, which is a diatonic step III for a C major tonality. When the tune begins on a neighboring step IV, the same proprioceptive program produces a version of the tune in a minor mode (the “little lamb” becomes “sad”). When the tune begins on a supertonic D, the produced version becomes enveloped by a tritone B–F (*diabulus in musica*), unpleasantly distorting the melody. In both cases, a shift along the piano keyboard is rather small – just to a neighboring white key – but the musical consequences of the shifts are dramatic. A shift one step up changes the mode of a tune from major to minor, and a shift one step down strips the tune of its modal certainty. But the motor/proprioceptive program is identical for all three presented versions of “Mary Had a Little Lamb.”

Figure 12: Three versions of a tune “Mary Had a Little Lamb” 1. in the C major tonality; 2. in the D minor tonality. 3. modally ambiguous appearance of the tune (Public Domain: Roud Folk Song Index number of 7622)

In music performance, the proprioceptive system adapts to the demands of the musical meaning. Sometimes, a segment of a motor program conflicts with a musical image, and this forces a musician to labor to overcome the problem by adjusting the sensitivity of touch and adroitness of fingers. To suggest that the motor behavior of a musician dictates musical meaning is akin to suggesting that a skillful movement of a tongue produces the meaning of words. While it is true that the movement of hands in music performance and the movement of tongue in speech are involved in the production of the respective musical and linguistic meaning, the hierarchy of contribution situates human mind above the physical performance by the limbs and tongue (Jakobson, 1981).

Moreover, the apparent corporeal articulation does not have enough resolution to convey the subtleties of tonal/temporal organization that is at the heart of musical meaning. For example, in measure 17 of the Chopin *Etude in C major* (Figure 6), a C major tonality (the "happy" one) is followed suddenly by an A minor tonality (the "sad" one), which immediately affects the character of the music. And while the motor program for fingers is different for a passage in C major tonality as compared to a passage in A minor tonality, this does not affect the general appearance of a pianist's gestures for playing the arpeggios swiftly up and down. The juxtaposition of harmonies and the delicate expressive timing become embedded in the precise touch of the pianist's fingers, their performance conveying the subtleties of meaning of the Chopin's music.

When observing the recorded performances of some great musicians such as Jascha Heifetz and Maria João Pires, one cannot fail to notice an economy of apparent corporeal movements during some extraordinary difficult moments in profoundly meaningful musical compositions. The quality of sound and virtuosity come with the years of intensive and focused practicing, and the economy of apparent efforts in music performance by professional musicians places them apart from the amateurs and beginner students. The ability to perform virtuoso musical compositions has its correlates in brain plasticity. Data from the research in the musicianship-related brain plasticity show that the motor behavior of musicians differs from the motor behavior of non-musicians (Gazer & Schlaug, 2003; Hyde, Lerch, Norton, Forgeard, Winner et al., 2009; Schmithorst & Wilke, 2002; Wan & Schlaug, 2010). Years of practicing a musical instrument generate changes in white matter structures of the brain, including the *corona radiata* and *internal capsule* (Schmithorst & Wilke, 2002) that are involved in the fine motor control; these changes suggest that professional musicians develop the strings of well-rehearsed movements for their psychomotor gestalt-actions. Therefore, with regard to apparent corporeal articulation, "auditory-motor mapping" (Schiavo et al, 2014) differs for music listeners without musical training as compared to professional musicians. The experience-dependent brain activation for music-related apparent motor behavior contrasts with the inborn sensitivity of listeners to the consonant and dissonant melodic compounds (Virtala et al., 2013).

The presented two-level model of embodied cognition in music emphasizes the dependence of music-related motor behavior on the intrinsically musical aspects that are best to discuss in terms of the core musicology and neuropsychology of music perception and production. As Eugene Montague (2011) writes in relation to the hard problem of consciousness in music, there is a need “to connect functional analytical explanations to the totality of musical experience” (Montague, 2011, p. 31).

EMOTION IN MUSIC: VIRTUAL EXPERIENCE OF PSYCHOLOGICAL TIME

Perhaps the most difficult problem in a field of music perception and cognition is the understanding of the mechanisms of emotional processing in music. Emotional processing in music involves an interaction of tonal time-space with the affective neurobiology.

The tonal space of music is generally explained in terms of the *circle of fifths* (Diletsky, 1677), where tonal centers are arranged according to tonal distance. During reorientation in the tonal space, a greater amount of steps between two tonal centers generates a tenser, colder and darker response from the listeners than a near-key tonal distance (Korsakova-Kreyn & Dowling, 2014). The data support the musicological theory that various distances within the tonal chronotope define the intensity of perceived tension. By interpreting the data in the context of affective neuroscience (Panksepp, 1998, 2005), Korsakova-Kreyn and Dowling propose that the sequencing of the tonal relationships in music imitates the dynamics of the integration of somato- and visceromotor information involved in the generation of non-musical emotions; this “internal” information is intrinsic to the formation of tonal/temporal structures that convey musical images of psychological time.

The mechanisms that empower music to affect psychological states of listeners and generate changes in their vital signs (Bernardi et al., 2006; Koelsch & Siebel, 2005; Trappe, 2012) and neurochemistry (Chanda & Levitin, 2013) are still not well understood. As shown by Krumhansl (1997), merely averaging physiological measures during music listening does not explain the dynamic nature of musical emotions. Even musical compositions exhibiting a definite character (e.g. joyful, sad, fearful) generate a mixture of diverse affective responses (Krumhansl, 1997). Some of the musical emotions are so intense that they provoke tears and shivers (Panksepp & Bernatsky, 2002; Sachs et al., 2016; Salimpoor, Benovoy, Longo, Cooperstock & Zatorre, 2009).

It is interesting that music perception seemingly verifies the concept of “negativity bias” (Ito, Larsen, Smith, & Cacioppo, 1992; Rozin & Royzman, 2001). In neuroscience, the negativity bias means that a greater amount of neuronal resources is dedicated to processing negative information as compared to positive information; this disparity is related, most likely, to the survival of the fittest (Spencer, 1864). The data show that sad music is a stronger generator of chills than merry music (Panksepp, 1995), and that the biological reward system responds with greater intensity to sad music (such as Rachmaninoff's *Piano Concerto No 3 in D minor*) than to happy music (Blood & Zatorre, 2001). Furthermore, the fine art of music is able to grant a cathartic experience (Nietzsche, 1872/1995).

By extrapolating Barsalou's (1999) theory of perceptual symbol systems onto the musical domain, Zbikowski suggests that a collection of emotional engrams, similar to semantic memory for categories of perception, might exist for music perception (Zbikowski, 2011). However, the suggestion that emotional processing in music relies exclusively on "emotional responses which we have already experienced" (Zbikowski, 2011, p. 54) is problematic, considering that some young musicians show remarkable sensitivity to musical thinking, despite having very modest life experiences (Kissin, 1985). Most likely, musical emotions are not merely the casts of already experienced complex psychological states, but the product of virtual reality of emotions. Like literary and cinematographic images of a love affair or loss of a child, which could be vividly imagined without being experienced in real life, the suggestive images of music offer an experience of psychological time.

The ability of music to generate aesthetic emotion and to activate the biological reward system speaks to the possibilities of therapeutic effects (Altenmüller & Schlaug 2015). The accumulated data on music-related bodily movement and entrainment (Burger et al., 2013; Leman et al., 2009, Leman & Maes, 2014; Naveda & Leman, 2010; McGuiness & Overy, 2011 Su, 2016) contribute to our understanding of the effects of music therapy for patients with motor disorders. For example, both entrainment and corporeal articulation have been integrated into neurological musical training (NMT) and rhythmic auditory stimulation (RAS), which help to improve motor behavior in patients with Parkinson's disease (Ashoori, 2015; Bukowska, Krężałek, Mirek, Bujas, & Marchewka, 2015, Hausdorff, et al, 2007; Moens, Van Noorden, de Wilde, Lesaffre, Cambier et al., 2017).

CONCLUSION

The presented two-level model of embodied cognition in music identifies the hierarchical relationship between the apparent corporeal behavior of music performers and listeners (the "surface" level) and the tonal/temporal program of a musical composition (the "deep" level). According to this model, musical meaning dictates the psychomotor behavior of musicians and music listeners.

The two-level model relies on the concept of perceived tonal tension, principal for the theoretical foundations of pitch space, functional analysis of musical form and empirical studies in music perception and cognition. Music theory and the philosophy of music explicitly connect perceived tonal tension to tonal expectations that are the source of melodic intentionality and musical motion in the acousmatic space of music. The empirical evidence for a link between perceived tension and real physical tension contributes to strengthening the theoretical foundations of embodied cognition in music.

By focusing on the principal dimensions of music – the tonal space and arrow of time – the presented paper highlights the motion-generating potential of the tonal relationships. The deviations from and restorations to tonal stability generate tonal expectations that translate into a sense of musical motion. In contrast, such reactions to music as gestures, dance, tapping, nodding, moving together and so forth represent apparent bodily interpretation of the heard music's content. In other words, the affordances of the "surface" level are affordances of music that is part of a spectacle, whereas the affordances of the "deep" level are affordances of music on its own. The "surface" and "deep" levels of embodied cognition in music are connected by research in the psychomotor behavior of musicians, including studies in proprioception and musicianship-related brain plasticity.

The presented paper proposes that Gibsonian ideas apply effectively to the "deep" level of tonal expectations, melodic intentionality and musical development, which all rely on the affordances of tonal space and expressive timing. By elucidating the link between perceived tonal tension and physical tension, the model connects emotional processing in music with the non-apparent motor activity in music listeners; the non-apparent motor activity is generated in response to the consonant and dissonant compounds and the stable and unstable tones. An intuition for the tonal hierarchy allows listeners to recognize music in an acoustic array and to differentiate between music and speech and between music and environmental noise. In addition to tonal-temporal relationships, other aspects of musical expressiveness contribute to eliciting emotions, including tempo, rhythm, expressive timing, melodic contour, diapason, accentuation, timbre, texture, variations in sound volume, and so forth. The highly pliable matter of music, with its many degrees of freedom that are supported by a robust perceptual schema, allows for creating the virtual images of complex emotions.

The most important argument for the proposed two-level model is the link between tonal relationships, musical meaning and motor behavior. According to the proposed model, listening to music triggers a pattern of non-apparent motor responses timed according to a tonal-temporal program of a musical composition. The fundamentally temporal experience of music is shaped by the aural force field generated by the tonal relationships. The sensation of tonal gravitational pull allows for creating the patterns of perceived tonal tension, which are tied to physical tension. The connection between perceived tonal tension, core musicology and real physical tension makes a claim to musicology-based theoretical foundations of embodied cognition in music.

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