Rhythm perception and music cognition

a brief survey[1]

Letícia Dias de Lima[2]

Universidade Estadual Paulista | Brazil

Abstract: How does our mind process musical rhythm? Based on recent researches and theories on music cognition, the present paper seeks to clarify this question by discussing some issues related to rhythm perception, such as the mental processes involved in the recognition, coding, and retrieval of rhythm and the influence of enculturation and formal musical training on these processes.

Keywords: Rhythm, music perception, music cognition.

---

[1] Submitted on: 30th September 2017. Approved on: 17th December 2017.

[2] Master candidate at UNESP (Institute of Arts) under the supervision of Prof. Dr. Marcos Mesquita, where she is a member of the "Percepção Musical" study group, coordinated by Prof. Dr. Graziela Bortz. Holds a degree in Music with Qualification in Popular Piano (FMU-2011). She started her music studies at the age of thirteen at the Conservatório Vila Mariana (founded in 1957), where since 2008 she teaches piano lessons and develops didactic materials for the popular piano course. She performs as pianist and composer of Brazilian instrumental music in the project *Trio Lá do B*. E-mail: leticiadiaspiano@gmail.com

There is no need for appealing to research or theories to imagine the complexity that the simple concept of "rhythm" encompasses. It may be considered, at least, as an idea related to time and movement. But how do these relations occur in music? How is rhythm organized? What elements belong to its structure? How does rhythm manifest itself in music? And how do we, listeners, perceive it? After all, how does our mind process musical rhythm?

In this paper, we will seek foundations to clarify these issues. We will discuss some concepts that are part of the rhythmic structure in general and the cognitive processes involved with their perception. Certainly, one of the factors that results in the complexity of rhythm is its multi-leveled nature (DAWE; PLATT; RACINE, 1993). Accented beats imply a sense of meter which, in turn, can be seen as the result of a cognitive process of grouping; the musical tones are grouped by the perception, also under influence of tempo, forming units in different levels; the interaction of these units with meter generates rhythm. And so, the elements are recursively connected. The organization of this paper in sub items lies precisely in the necessity of accessing the rhythmic complexity through a detachment of its dimensions. Thus, the issues brought by research and cognitive theories on rhythm perception will also be more easily understood.

Beat, accent, meter, grouping – besides the specificities of the concept of rhythm itself – are some of the objects commonly treated and thus subdivided in these researches and theories. The pioneers Lerdahl and Jackendoff (1983), for example, have already pointed that meter and grouping are different aspects of rhythm. Researchers often focus on specific aspects of rhythm (DAWE; PLATT; RACINE, 1993; THOMPSON and SCHELLENBERG, 2006), both in the elaboration of cognitive theories and in the development of experiments, where only one particular element is usually tested.

1. BEAT

One of the first rhythmic manifestations we can observe in human behavior is the capacity to synchronize movements with music. Children that "clap along the music" are examples of our ability to respond physically to beat perception. Beats are described by Lerdahl and Jackendoff (1983: 19) as "idealizations, utilized by the performer and inferred by the listener from the musical signal". The authors use a spatial analogy in which beats, which occur in time, are like geometric points, whereas durations correspond to spaces between these points – named time-spans. Time-spans, therefore, have duration, yet beats do not. Kramer (1988: 97) sustains this idea and claims that we do not exactly hear beats: "We experience them, we feel them, and we extrapolate them – by means of mental processing of musical information. But we cannot literally hear something that is a timepoint, that has no duration".

Cooper and Meyer (1960: 3) acknowledged beat sense's proclivity to remain "in the mind and musculature of the listener, even though the sound has stopped". Recent research shows that the brain does indeed synchronize with rhythms from the environment, responding to regularity patterns, and that this synchronization occurs even in the case of stimulus from an expected event that does not occur[3] (TAN; PFORDRESHER; HARRÉ, 2010). Patel and Iversen, in their 2014 paper "The Evolutionary Neuroscience of Musical Beat Perception", discuss some fundamental aspects of beat perception, such as (1) its anticipatory nature, (2) its constructive nature and (3) the connections between beat and brain's motor areas.

The authors observe that, when synchronizing movements with clicks of a metronome, human beings tend to precisely predict the time of subsequent beats; that is, beat perception is a predictive process. For Huron (2006), this "expectation generator" is an entirely unconscious process, whose biological aim is to predict future events. This prediction has the purposes to minimize the expenditure of energy – optimizing our arousal levels – and to facilitate attention. "When listening to sounds, we do not pay attention equally at all moments. Instead, auditory attention is directed at particular moments in time. Specifically, attention is choreographed to coincide with the most likely moments of stimulus onsets" (HURON, 2006: 176).

Patel and Iversen (2014) point to an experiment developed with monkeys by Zarco et al. (2009), which shows that, after extended periods of training, monkeys were conditioned to synchronize movements with a metronome, but that happened as a reflex – approximately 100ms after each click. Hence, they showed themselves to be incapable of anticipating beats. The results suggest that this may be an exclusive human capacity.

The second characteristic of beat perception highlighted by Patel and Iversen (2014) is that it involves not only the "discovery" of periodicity – a result of passive hearing. It is also a constructive process, subjected to the listener's voluntary control, especially in songs whose cues are ambiguous. Both predictive and constructive processes implicate in active relations of expectation and future projection. Kramer (1988) claims that musical hearing is a compound of this active participation with a passive "observation". The latter happens when the spectator gradually develops mental representations[4] while listening to a musical piece, in a process of cumulative listening that involves memories of past events. Both expectations and memories are part of the perception process, which always happens in the present moment of hearing.

Even when we just listen to music – without performing gestures and movements – we seem to synchronize with an internal beat (NOORDEN and MOELANTS, 1999). Patel and Iversen (2014),

[3] See Snyder and Large, 2005 *apud* TAN; PFORDRESHER; HARRÉ, 2010: 107.
[4] "The concept of mental representation [...] refers to the internal reconstruction of the outside world" (LEHMANN; SLOBODA; WOODY, 2007: 19). According to these authors, the individual reconstructs the outside world in order to act effectively on that information.

finally, cite this important finding in the neuroscience of beat perception, which is its engagement with motor areas of the brain even in the absence of any movement manifestation, along with the increase of functional coupling between auditory and motor regions[5] – apparently stronger in musicians than in nonmusicians[6].

As the initial example of children clapping along the music, the motor response to beat perception is an evidence of the "listener's sensitivity to musical timing regularities" (JONES, 2009: 81) and can be assessed – both in laboratory conditions and in a music classroom – through simple actions, such as tapping a finger or hand on a surface, clapping or even dancing (NOORDEN and MOELANTS, 1999; KARPINSKI, 2000; ECK, 2001; JONES, 2009; NOZARADAN et al., 2011; PATEL and IVERSEN, 2014). According to Karpinski (2000: 20) "of all the abilities involved in temporal aspects of music listening, perception of the pulse is perhaps the most fundamental". Honing (2013) states that researchers are still divided about the basis of this ability, that is, if it is developed spontaneously or if it is learned somehow – revealing biological or cultural origins, respectively.

Paul Fraisse (1976) brings the notion that our beat perception is associated to cadential movements[7], like the newborn suction while being fed, our ingestion and chew, and the way we walk. The velocity in which these movements or regular beats occur is what we could call tempo, the absolute time in music, which refers to "the number of beats per unit time" (KRAMER, 1988: 349). Tan, Pfordresher and Harré (2010) argue that the way we move may be connected to our bias for tempos with beats around 600ms – approximately 100 bpm (PARNCUTT, 1994; NOORDEN and MOELANTS, 1999; LONDON, 2012), and claim that this measure is similar to the velocity in which people usually walk.

We are led to believe that the naturalness of such movements, given its generality, relates to purely biological origins. After all, cadential movements are found in birds' flights, fishes' swim and, of course, in human beings (FRAISSE, 1976). Notwithstanding, the subject that listens to a musical piece is a human being but also an enculturated one and, sometimes, formally trained. In the case of enculturation, it is worth considering that "'all cultures have sound patterns with repetitive temporal structures, which facilitate synchronous dancing, clapping, instrument playing, marching, and chanting' (BROWN, 2003). These communal activities imply universal propensities to coordinate movement in time" (HANNON and TREHUB, 2005: 48). It remains to know to what extent biological, cultural, and educational factors concern the listener's choices about beats – and, as a consequence, about tempo – while listening to a musical piece.

---

[5] See Kung et al., 2013 *apud* PATEL and IVERSEN, 2014: 4.
[6] See Grahn and Rowe, 2009 *apud* PATEL and IVERSEN, 2014: 4.
[7] For Paul Fraisse (1976), cadential movements imply the definition of cadence as the repetition of isochronous intervals of a sound or a movement.

2. METER

When we talk about meter, we talk about a framework of beats organized hierarchically. For such a hierarchy to exist, beats cannot be the same, but interact in different perceptual levels. Hence, it is not possible to approach metrical issues without stating, first, the notion of accent (LERDAHL and JACKENDOFF, 1983; BERRY, 1987). A stimulus that highlights itself to consciousness is an accent – a relational concept, because “there can be accents only if there are unaccents” (COOPER and MEYER, 1960: 8). Or, as Berry (1987) states, the accent denotes a relative strength of an auditory event, if compared to its contiguous events.

Lerdahl and Jackendoff (1983) distinguish three kinds of accent: phenomenal, structural, and metrical. Phenomenal accents – based on sensorial sources – are events that give emphasis to some moment of the musical flow, such as changes in intensity, pitch, and duration; structural accents are points with some melodic or harmonic gravity, like a cadence – whose “weight” is perceived by its structural relations[8]; and a metrical accent consists of a relatively strong beat in its metrical context. This kind of accent is seen by the authors as a mental construct (see Patel, 2008), inferred by the musical surface’s accentuation patterns. Phenomenal accents function as cues[9] from which the listener attempts to extrapolate a regular pattern of metrical accents. “[...] the listener's cognitive task is to match the given pattern of phenomenal accentuation as closely as possible to a permissible pattern of metrical accentuation; where the two patterns diverge, the result is syncopation, ambiguity, or some other kind of rhythmic complexity” (LERDAHL and JACKENDOFF, 1983: 18).

This concept corroborates with what Kramer (1988) calls metric accent, especially for the fact that he also places it, at least partially, as a psychological phenomenon. The cadence (structural accent, for Lerdahl and Jackendoff) is seen by Kramer as a point of rhythmic accent; and he names phenomenal accents as stress accent. Generally, perception is based on processing both acoustic data of the musical surface – like phenomenal or stress accents – and intellectually acquired data – like structural accents (DAWE; PLATT; RACINE, 1993).

Even though different terms can be found in the literature, an important factor to be discussed is the distinction between events present in the musical surface and patterns resulting from cognitive processes, such as the inference of metrical accents from phenomenal accents: “[...] the listener instinctively infers a regular pattern of strong and weak beats to which he relates the actual musical

8 "Structural accents result from more abstract properties and cognitive principles associated with tonal and diatonic organization" (DAWE; PLATT; RACINE, 1993: 795).

9 Palmer and Krumhansl (1990: 730) find it unlikely that only phenomenal accents determine meter, and place repetition as another perceptual cue for metric inference, "assuming that a repeated pattern will occur in the same metric position (within a bar) on its different repetitions".

sounds. [...] our term for these patterns of beats is *meter*" (LERDAHL and JACKENDOFF, 1983: 12).

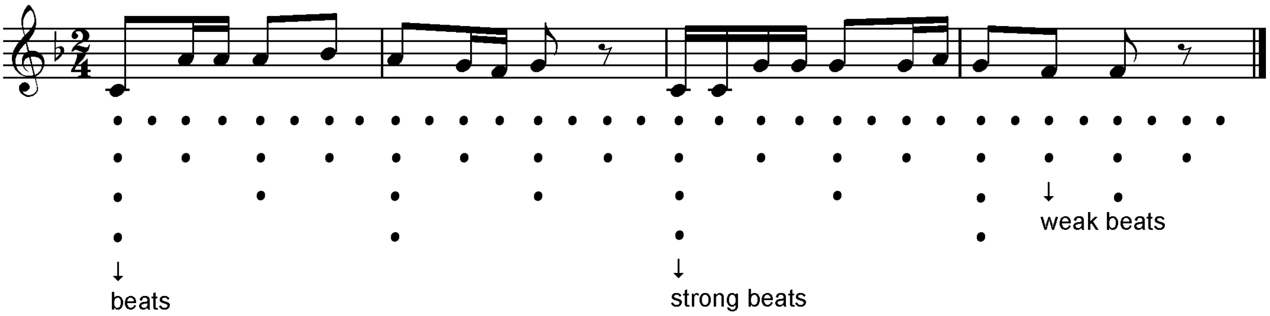

Fig. 1 – Each line of dots represents a beat level. Places where many beat levels align are points of metrical accent. Adapted from LARGE, Edward W.; KOLEN, John F. Resonance and the Perception of Musical Meter. *Connection Science*, v. 6(2-3), p. 177-208, 1994.

According to Huron (2006: 179), "what musicians call the 'strength' of a metric position is correlated with the likelihood of a tone onset". Strong beats, for example, are metric positions more inclined than others to coincide with tone onsets. Some researches[10] point out that tone onsets coincident with these positions are judged by listeners as "more appropriate" to the metrical context.

The strong-weak notion implies hierarchy – two or more levels of beats (LERDAHL and JACKENDOFF, 1983; TAN; PFORDRESHER; HARRÉ, 2010) – and is also cited by Cooper and Meyer (1960: 5) as determinant to meter's own existence. These authors acknowledge the "architectonic" nature of meter and state that "most compositions present a hierarchy of metric organizations". However, when they assert that "some of the pulses [...] must be accented" (COOPER and MEYER, 1960: 4), they seem to locate such accents in musical events themselves: "strong" beats are accented, while unaccented are called "weak". At this point, the idea differs from Lerdahl and Jackendoff's ideas, as well as Berry's definitions do.

This author admits that our beat sense is a psychological phenomenon, but also that imposed to this sense are the real sound events (sounds and silences) that, grouped by various kinds of distinction, form the metrical structure. "Meter is thus an aspect of grouping" (BERRY, 1987: 320). Grouping, as an organizing tool of our perception, is a cognitive process that, indeed, has on meter one of its possible results. Though, as a structural aspect of music, grouping presents sound units in different hierarchical levels – such as small melodic groups, phrases, sections and movements of a piece – and this implies segmentation, something that does not occur with meter[11] (TEMPERLEY, 2001). For Berry (1987: 317), then, meter is an inherent aspect of musical structure, articulated through accents:

[10] See Palmer and Krumhansl's (1990) second experiment, "perceptual hierarchies".
[11] Meter and grouping differ fundamentally at this point: grouping consists of hierarchical organizations of *units*, and meter, of *beats* (LERDAHL and JACKENDOFF, 1983).

"the question of meter is the question of accent".

Kramer (1988: 82) refers to meter as a standardized succession of accented timepoints and claims that every musical parameter potentially contributes to induce metric accents: "music itself determines the pattern of accents we interpret as meter [...] Music not only establishes but also reinforces and sometimes redefines meter". Even considering that musical events give us information about which timepoints are meaningful (accented), we do not literally hear the degree of metrical accentuation of these points, but we infer it. "[...] in many cases inferring a meter does not involve extracting invariant information [...] but rather matching the musical figure against a repertoire of well-known rhythmic/metric templates" (LONDON, 2012: 67). "Musical beats and meter periodicities are perceived from sounds, whether or not these sounds are actually periodic. Indeed, they can be induced not only by isochronous pulses (as with a metronome) but also by complex rhythmic structures" (NOZARADAN, 2014: 3).

When we experience beats, therefore, we do so through a psychological process, abstracted, and interpreted from perception. In this manner, meter is a predictive schema for temporal events (HURON, 2006) constituted of beats, not tones; that is, a cognitive process, instead of purely musical elements. "It should not be surprising, therefore, that there is no readymade vocabulary for metric units on hierarchic levels above that of the measure" (KRAMER, 1988: 98), the way it does for grouping units (tones) – such as "motives", "phrases" and "sections".

"The beauty and richness of musical meter lies precisely in the impossibility of totally objectifying it" (KRAMER, 1988: 109). The matter of subjectivity – naturally provoked by the establishment of metrical perception as a cognitive process – has been discussed by many authors, especially when distinguishing the concepts of meter and rhythm. Even though such distinction is not unanimous – as questioned by Hasty (1997) – there is a general agreement regarding the differences between meter and rhythm.

> [...] meter involves our initial perception as well as subsequent anticipation of a series of beats that we abstract from the rhythmic surface of the music as it unfolds in time. In psychological terms, rhythm involves the structure of the temporal stimulus, while meter involves our perception and cognition of such stimuli (LONDON, 2012: 4).

"[...] a process in which one rhythmic pattern achieves and maintains synchrony with another pattern" (TAN; PFORDRESHER; HARRÉ, 2010: 105) is named *entrainment*, a rhythm perception approach whose basic idea is that people possess internal rhythms that adapt themselves to musical rhythms. These authors observe that this is due to the fact that our brain's activity is inherently rhythmic; thus, our affinity with musical rhythm exists because our brain synchronizes with rhythms of the environment. Nozaradan (2014) reinforces this idea by claiming that our perception of periodicities generally involves a spontaneous entrainment of movements synchronized with it. This view can explain the fact that "for many people, [...] synchronization is a natural part of musical experience requiring no special effort" (PATEL, 2008: 100).

London's assumption in his book "Hearing in Time" (2012) is that meter is a form of entrainment behavior. He adds that this happens as a more general behavior, "not fundamentally musical in its origin. Rather, meter is a musically particular form of entrainment [...], a synchronization of some aspect of our biological activity with regularly recurring events in the environment" (LONDON, 2012: 4). He locates the matter of accent in the entrained listener, so that "metric accent becomes a natural fallout of the attending process" (2012: 19). Furthermore, he states "it is the differentiation of expectation, rather than any tonal or durational criteria, that gives rise to different degrees of metric accentuation, and the subjective sense of a pattern of strong versus weak beats" (LONDON, 2012: 16).

Honing (2013) emphasizes the possibility of a processual predisposition of human cognition to extract hierarchically structured regularities from rhythmic patterns, even if they are complex. This bias involves a listener's sense of distinction of the stimulus in "two, three, or four", for example; such kind of inference is due to the selective nature of attention, which leads us to focus on salient temporal events in the midst of a plethora of stimulus from which we are incapable of extracting all information[12]. Thus, the sense of meter possibly emerges from the need we have for clustering stimulus in small groups, even if those are absolutely identical – as clicks. This sense of meter is called subjective metricization[13] (LONDON, 2012; THOMPSON, 2015; LARGE and KOLEN, 1994), and can vary due to factors such as age, training and enculturation (LONDON, 2012).

Cirelli et al. (2016) declare there are evidences showing that humans as young as babies are sensitive to beat and meter perception. They developed experiments with seven and fifteen months old infants in which was demonstrated that their musical experiences and their parents' musical experiences – that is, enculturation – influence neural responses entrained by beat frequencies. Apparently, such experiences may shape their musical listening. The authors also claim that musicians perform better than nonmusicians in tasks involving perception and production of meter, which shows that formal training affects such activities. Researches from Hannon and Trehub (2005) also indicate the influence of enculturation on meter perception, and suggest that infants absorb metrical structures through music exposure during the first year of life.

[12] This principle was proposed and widely developed by Mari Riess Jones under the term *rhythmic attending*, which proposes that attention increases and decreases according to periodic pulses; thus, listeners are more attentive to particular temporal moments.

[13] London (2012: 13) renames the so-called *subjective rhythmization*, a term used by authors such as Bolton (1894) and Meumann (1894): "This is something of a misnomer, for what is really subjective is [...] a sense of meter under which the tones or clicks are heard, and thus perhaps *subjective metricization* would be a better term".

Assuming that "[...] comparisons between infant and adult listeners could reveal biases that stem from musical enculturation or from perceptual predispositions" (HANNON and TREHUB, 2005: 49), the authors developed three experiments in order to assess listeners' perceptive bias in relation to ratios of durations. They exposed subjects to folk tunes with distinct metrical structures (simple or complex[14]) and then modified the stimulus so that the original metrical structure was preserved or violated. In the first experiment, North-American adults were capable of listening to violations of metrical structures in simple metric patterns, but not in complex ones. According to the authors, such difficulty in encoding unconventional sequences may be originated in the inappropriate assimilation of sequences that are atypical to musically familiar categories – which is consistent with processes of musical enculturation.

In the second experiment, adults from Bulgaria and Macedonia (who had some formal training in Western music) were able to assess the preservation and violation of metrical structures in both simple and complex meter standards. This ability may lie in the fact that participants were exposed to both simple and complex meters experiences, which is also consistent with enculturation. In the third experiment, which investigated innate auditory preferences, six-month old infants identified violations in both metric contexts; this suggests that human listeners, at first, process metrical structures with flexibility, which facilitates the perception of temporal nuances in various kinds of music.

The authors argue that years of exposure to the metrical categories that dominate in a specific musical culture should induce perceptual reorganizations and the narrowing of metrical structures that can be easily manipulated. These findings reflect the influence of processes of enculturation – rather than predispositions for simple meters – on the metric preferences of adult listeners. This is in line with their initial hypothesis that, "regardless of the presence or absent of infant biases, adult attunement to the metrical categories of their musical culture should lead to enhanced processing of culturally typical duration ratios" (HANNON and TREHUB, 2005: 49). Huron (2006: 201) corroborates this idea: "listeners best process those rhythms that occur most frequently [in the repertoire]".

As a result of mechanisms with cultural and biological basis, the rhythmic synchronization of entrainment leads to the anticipation of regular beats subsequent to the initial perception of meter. It is a phenomenon that depends much more on the listeners' ability to generate metric patterns than on the sound stimuli themselves, which need not to be absolutely invariable for the initial interpretation of meter to remains the same. "Once a clear metrical pattern has been established, the listener renounces it only in the face of strongly contradicting evidence" (LERDAHL and JACKENDOFF, 1983: 17), such as, for example, the clear emergence of an altered metric pattern.

---

[14] Basically, simple meters have a 2:1 ratio (common in Western tonal music), and complex meters, 3:2 (common in Eastern European cultures, for example).

Lerdahl and Jackendoff (1983) establish that metrical structures have the function of marking musical flow, as far as possible, in equally spaced beats. In this way, meter, that "can be understood [...] as fundamentally regular" (KRAMER, 1988: 102), allows the listener to create expectations[15]; these, in turn, "guide 'anticipatory pulses of attention' that facilitate perception of events that occur at expected points in time" (LARGE and KOLEN, 1994: 183). We can conclude, therefore, that the concept of meter is related to regularity. It is worth emphasizing the notion brought by Huron (2006: 201) that periodicity is "simply a special case of the more general phenomenon – predictability", which is the temporal basis of our perception. Thereby, the function of meter is linked to the perceptual organization of music.

Palmer and Krumhansl study meter organizing function in a research that focuses on the nature of mental representations of meter. The authors present "evidence indicating that abstract knowledge of meter affects comprehension, memory, and composition of Western tonal music" (PALMER and KRUMHANSL, 1990: 728). They conclude that listeners refer to the knowledge of temporal regularities contiguous to music to encode and remember musical events, affecting the perceived association between events, and producing a mental representation of coherence between multiple metrical levels.

> [...] musical perception involves the recoding and organizing of musical material through reference to a more abstract system of knowledge about musical structure. This abstract knowledge often represents the underlying regularities found in one's own musical culture, such as a particular tonal system or common metrical properties. These mental structures may facilitate comprehension of global aspects of musical structure and lead to expectations about future events. Thus, [...] meter may provide a (time-based) framework from which temporal expectations are formed (PALMER and KRUMHANSL, 1990: 728).

Within this context, London (2012: 14) brings the idea that meter is much more than a regular response to musical stimuli; it functions as a useful – and perhaps necessary – background upon which temporal patterns can be discerned. "[...] metric context has a strong effect on our sense of the structural (as opposed to ornamental) tones of many melodic patterns". Hannon and Trehub (2005) also point out that the implicit knowledge of metrical structure, which undoubtedly varies between cultures, is central to the perception of rhythmic patterns. In the case of Western tonal music, "metrical levels of accent are constrained by a strict nested hierarchy of binary and ternary beats, with the requirement of equal durations between beats at each level" (PALMER and KRUMHANSL, 1990: 728).

[15] Periodicity facilitates the formation of temporal expectations, but is not necessary for this. It is enough that the listener is familiar with a particular time framework and that some element of this pattern is predictable (HURON, 2006).

Metric classification	Sample meters	Percent occurrence
simple duple	2/2, 2/4, 2/8, 2/16	27,4
simple triple	3/2, 3/4, 3/8, 3/16	32
simple quadruple	4/2, 4/4, 4/8, 4/16	27,2
compound duple	6/2, 6/4, 6/8, 6/16	9,4
compound triple	9/2, 9/4, 9/8, 9/16	1,3
compound quadruple	12/4, 12/8, 12/16, 12/32	1,9
irregular	5/4, 7/8 etc.	0,8

Tab. 1 – Results of a survey of thousand musical works from the Western classical tradition, based on Barlow and Morgenstern's "Dictionary of Musical Themes" (1948) (HURON, 2006).

We can see in table 1 that in Western tonal music there is a preference for binary grouping of beats and subdivisions (HURON, 2006). It is possible that this cultural feature, more than an innate disposition, justifies the tendency of (Western) listeners to impose binary meters on identical stimuli. Other considerations regarding the implications of meter on rhythmic perception will be discussed below.

3. RHYTHM

The inaccuracy involved in more restricted and objective concepts of rhythm can be exemplified by Cooper and Meyer's (1960) statement that rhythm is the way one or more beats are grouped in relation to an accented beat. Such definition, in fact, approaches the idea of meter, not of rhythm. This is one of the problems involved in researches and theories on rhythm perception: "several researches employ the term 'rhythm' in reference to different phenomena" (DAWE; PLATT; RACINE, 1993: 794). A clearer idea is brought by Tan, Pfordresher and Harré (2010: 96): "[rhythm] is the time pattern created by notes as music unfolds over time". They highlight some key factors that are part of this concept.

First, rhythms "rely on the presence of tone onsets. Metrical accents [...] can exist when no tone is there" (TAN; PFORDRESHER; HARRÉ, 2010: 102). Another element is the typical variability of rhythm as opposed to the regularity of meter. Kramer corroborates these ideas:

> A measure is cyclic, in that after the music has moved through beats 1, 2, 3, and 4 (for example), it goes back to (another) beat 1. Rhythmic groups are not usually cyclic, because they vary considerably and because they are comprised of music, not just beats. It is because meter is cyclic that it is more resistant to change than is rhythm. Rhythm is a force of motion, while meter is the resistance to that force. Rhythm *can* change the meter, but only with difficulty (KRAMER, 1988: 83).

There is also the fact that rhythms are based on relative, not absolute time – as is the case with meter. "Rhythm [...] cannot depend on absolute time because the absolute time of every note changes when tempo changes. The fact that rhythms are based on relative time leads to the conceptualization of rhythmic relationships as ratios" (TAN; PFORDRESHER; HARRÉ, 2010: 97). It is clear, in this way, the distinction between rhythm and meter and their positioning as independent musical elements[16]. Nevertheless, there are evidences of the influence of metrical contexts on our rhythm perception.

The literature highlights the importance of the meter's role in our perceptual organization of music and how much metrical structures facilitate the efficiency of processing temporal patterns (TEMPERLEY, 2001). Rhythmic durations are more hardly perceived when they occur as isolated events (THOMPSON, 2015), since musical experience is based on the perception of sound relations – not on isolated sounds (TAN; PFORDRESHER; HARRÉ, 2010). "[...] the musical context of a musical passage greatly influences our mental representation of it. Metrical structure also influences other levels of representation such as phrase structure and harmony" (TEMPERLEY, 2001: 24).

Musical patterns can be interpreted differently, depending on their metrical context, also because "the listener's sense of meter arises from an interaction between abstract, context-free knowledge of meter and context-dependent knowledge from specific musical events" (PALMER and KRUMHANSL, 1990: 730). Rhythmic patterns combine two essentially different representations of time: the discrete rhythmic durations – as they are, for example, symbolized in a score – and the continuous temporal variations that characterize the expressive time of interpretations (DESAIN and HONING, 2003). This cognitive process, fundamental for our ability to perceive and execute expressive time, is called categorical perception[17]: mechanism whose idea is that "listeners assign the continuously variable durations of expressive performance to a relatively small number of rhythmic categories" (CLARKE, 1999: 490). Thus, it is only psychologically plausible to distinguish rhythm and expressive time because this mechanism is capable of separating them.

There is evidence of the relationship between the formation of rhythmic categories and the presence of a metrical context, as in the experiments of Desain and Honing (2003). Participants – highly trained musicians – were instructed to note the stimuli presented through an interface. In the second experiment the same stimuli of the first one were used, but contextualized in a metrical structure. The authors expected a greater consistency in responses to stimuli when a metrical context was presented, as well as changes in size and shape of rhythmic categories depending on these contexts.

16 "Some neuroscience research supports the presumed separation of rhythm and meter, in that perception of metrical organization is hindered by damage to the temporal lobe in either hemisphere, whereas the temporal lobes may not contribute to rhythm perception" (LIÉGOIS-CHAUVEL et al., 1998 *apud* TAN; PFORDRESHER; HARRÉ, 2010: 107).

17 "[...] we understand notes as being in one rhythmic category or another, rather than merely perceiving them as continually varying" (TEMPERLEY, 2001: 25).

Their hypotheses were confirmed and it was observed that the identification of stimuli was facilitated when presented in an appropriate metrical context.

The perception of durations is also subjective when it comes to its complexity and amount of information. Perhaps no one would disagree with Kramer's claim that a pop tune seems to last less time than a Webern's movement, even though both last exactly two minutes. "The more 'storage space' a passage requires, the longer its subjective duration" (KRAMER, 1988: 337). The elements that affect the amount of memory, and therefore the "remembered" duration, are (1) the amount of stimulus information and also (2) its codability. The former is more easily observed and measured; the second, in turn, is related to the degree of stimulus' complexity.

Sakai et al. (1999) conducted a study focused on the complexity of serial ratios. Participants should listen to and then reproduce rhythms based on integer (simple) or non-integer (complex) ratios. The brain activity involved in the retention of complex rhythms included additional activations to the motor areas ones – registered with simple rhythms – especially in the prefrontal cortex. As this area is related to working memory, this data suggests that complex rhythms have increased the memory load. In addition, they have been associated with a reduction in analytical processes. It was therefore concluded that the brain does indeed need to work harder while listening to a rhythmically complex piece.

At first, the idea that a Webern's movement has more information and is more complex than a pop tune is acceptable. However, it is crucial to consider that the rhythmic complexity of a piece is not only found in elements of the musical surface but also in the enculturated listener, who perceives the musical stimuli as simple or complex in relation to her/his own vocabulary.

4. GROUPING

According to Lerdahl and Jackendoff (1983: 12), grouping refers to the way in which "the listener naturally organizes the sound signals into units such as motives, themes, phrases, periods, theme-groups, sections, and the piece itself". It is therefore a general process of segmentation at all levels. We tend to hear notes grouped – not isolated – because we perceive a boundary between one unit and another. Grouping refers to the perception of these boundaries (PATEL, 2008) or, as McAuley (2010: 166) defines it, "[grouping] refers to how a series of notes are perceived to be clustered or grouped together". Grouping has the cognitive function of parsimony; if isolated elements can be grouped into a larger group, this action reduces the number of elements that must be recognized, stored and retrieved by memory: "it is much easier to remember a list of 10 words than a list of 70 letters" (TEMPERLEY, 2001: 56).

> The process of grouping is common to many areas of human cognition. If confronted with a series of elements or a sequence of events, a person spontaneously segments or 'chunks' the elements or events into groups of some kind. The ease or difficulty with which he performs this operation depends on how well the intrinsic organization of the input matches his internal, unconscious principles for constructing groupings. [...] Thus grouping can be viewed as the most basic component of musical understanding (LERDAHL and JACKENDOFF, 1983: 13).

The universality of "internal, unconscious principles for constructing groupings" – mentioned above – is widely accepted by researchers. However, attention has not been given to the influences of our experience on such principles (IVERSEN; PATEL; OHGUSHI, 2008). For this reason, these authors carried out a research in order to investigate if learning speech rhythms can be responsible for shaping basic preferences of auditory grouping. "[...] the issue at hand is whether learning the characteristic rhythms of meaningful units in the auditory environment (which is dominated by speech for humans) can shape low-level rhythm perception mechanisms" (IVERSEN, PATEL; OHGUSHI, 2008: 2264).

The results of this research suggest that grouping cognitive processes may be strongly dependent on culture. English and Japanese listeners have revealed different patterns in grouping perception, showing that this basic auditory process is not universal, but shaped by experience. Assuming that these differences reflect auditory experiences, the authors argue that they are due to the "most obvious source of cultural differences in auditory experience [which is] the dominant language of the culture" (IVERSEN, PATEL; OHGUSHI, 2008: 2268).

Huron (2006: 198) claims that, "once the auditory system begins to process a group of sounds, sounds that do not belong to the group are stored separately and dealt with later. [...] Rhythmic patterns [...] tend to be processed as mental 'atoms'". Therefore, as listeners, we organize sound signals in units, forming groupings at different hierarchical levels[18] (DEUTSCH, 2013; LERDAHL and JACKENDOFF, 1983; THOMPSON and SCHELLENBERG, 2006). This structural sense can be transmitted to the listener through a range of acoustic cues – such as frequency, duration, intensity, or timbre – and structural – like harmony. Events such as sudden changes in dynamics or timbre, relatively distant melodic leaps, local stresses such as *sforzando*, long notes, harmonic changes, and other patterns of change in these dimensions produce subjective accentuations that influence our musical elements' grouping perception (DELIÈGE, 1987; DEUTSCH, 2013; McAULEY, 2010).

In "A Generative Theory of Tonal Music" (1983) – hereinafter referred to as GTTM – Lerdahl and Jackendoff develop a grouping theory that can be applied in local and global structures of the process of musical listening. It describes two types of rules: well-formedness rules, which specify the

---

[18] Within this context, hierarchy means a (subordinate) unit belonging to another (dominant) unit. This process of subordination/domination can continue indefinitely, from local levels – as small melodic groups – to global levels – as an entire movement of a piece (LERDAHL and JACKENDOFF, 1983).

plausible structural descriptions of the musical surface and the preference rules, which "establish not inflexible decisions about structure, but relative preferences among a number of logically possible analyses" (LERDAHL and JACKENDOFF, 1983: 42) of structural descriptions that the listener attributes to music, relying on the perception of phenomenal accents. In developing the preferential rules, the authors "mean to express analytically the relations that the listener intuitively perceives, that is, the unconscious principles of his perceptual organization" (DELIÈGE, 1987: 327). These principles can be found in the classical studies of Gestalt theory[19] and seem to be general cognitive mechanisms also involved in speech processing and other auditory stimuli (PATEL et al., 1998). Two of them support preferential grouping rules: our tendency to group what is similar (similarity) and what is close (proximity) (TEMPERLEY, 2001).

The principle of proximity has been the most categorical clue that governs the perceptual grouping of musical patterns, both of time and pitch (DEUTSCH, 2013, HAMAOUI and DEUSTCH, 2010). In a rhythmic sequence – being equal the elements of other dimensions such as intensity, tempo, and articulation – the "natural" grouping is determined by the intervals between its events; therefore, it occurs under the influence of temporal proximity (TODD, 1994). Proximity refers to two preferential rules concerning temporal events: the *slur-rest rule* (R1) – segmentation at the end of slurs or rests – and the *attack-point rule* (R2) – the boundary is set after a prolonged sound among other short ones; the principle of similarity governs the rules of change in register (R3), dynamics (R4), articulation (R5), length (R6) and timbre (R7) (DELIÈGE, 1987).

Some authors point to problems found in GTTM. Frankland and Cohen (2004), for example, disagree with the joint of slur and rest in the same rule. For them, it is more consistent to combine slur with the change of articulation rule, which already includes *staccato* and *legato*. In addition, Temperley indicates that:

> [...] the theory can only accomodate 'homophonic' music in which a single grouping structure applies to the entire texture. Thus it works fairly convincingly for things like Bach Chorales. In much music, however, one feels that different parts of the texture demand different grouping boundaries (TEMPERLEY, 2001: 63).

This is a constraint that Lerdahl and Jackendoff admit: "For the more contrapuntal varieties of tonal music [...] out theory is inadequate" (1983, p. 37). Moreover, the theory was structurally conceived; it was not validated by tests involving human participants (MESQUITA, 2016).

In her 1987 article, Deliège describes two experiments she developed to test the validity of

[19] The psychology of Gestalt was extensively developed by groups of psychologists active in Germany around 1920. They proposed a set of principles that would govern the grouping of elements in our general perception. Their rules may seem a bit obvious or vague, and in fact psychologists have had little success in developing them within a more rigid theory. However, they provided useful starting points for recent research on grouping (TEMPERLEY, 2001).

preferential rules in musicians and nonmusicians. Participants were instructed to indicate the boundaries between groupings in Western classical music excerpts[20] (experiment 1) and simple melodic sequences (experiment 2). Nonmusicians had a relatively inferior performance in the first experiment. However, the author claims that musical training does not seem to elicit grouping interpretations radically different from those perceived by nonmusician listeners, but it seems to make memory more efficient. The limits perceived by participants broadly corresponded to GTTM rules.

Although preferential rules are based on "universal" principles of human perception, Lerdahl and Jackendoff state that the theory applies only to the listener who has experience in a certain musical idiom – such as Western tonal music; controversially, they also claim that "a listener needs to know relatively little about a musical idiom in order to assign grouping structure to pieces in that idiom" (LERDAHL and JACKENDOFF, 1983: 36). The authors do not explain the meaning of "experience in a certain musical idiom" or "to know relatively little", that is: we could assume they are talking about culture and formal training, respectively. But, essentially, the issue of enculturation is vague, and the role that formal training plays on the perception of grouping, in this theory, is not considered.

A notable cognitive aspect resulting from Deliège's research is that it "suggests the existence of two distinct mechanisms [...] in the treatment of musical data: the one specific to the duration of sound, the other specific to its acoustic qualities" (DELIÈGE, 1987: 356). Deutsch (2013: 184) corroborates this by stating that "grouping decisions are not made by a single, internally coherent, system, but rather by a number of different subsystems, which at some stage act independently of each other, and can arrive at inconsistent conclusions". Divergences occur when, for example, two or more rules compete with each other in different but contiguous events; in this case, segmentation will result from a choice between available possibilities (DELIÈGE, 1987). The figure below demonstrates a conflict between (a) a rule involving duration and (b) another involving an acoustic quality:

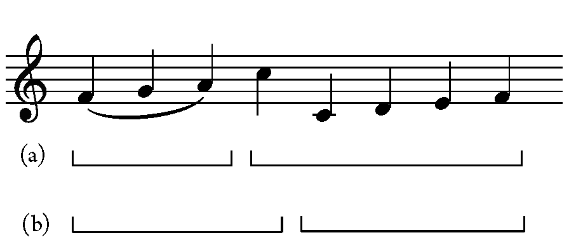

Fig. 2 – Conflict between (a) slur-rest (R1) and (b) change in register (R3). Adapted from DELIÈGE, Irene. Grouping Conditions in Listening to Music: An Approach to Lerdahl & Jackendoff's Grouping Preference Rules. *Music Perception: An Interdisciplinary Journal*, v. 4 (4), p. 325-359, 1987.

[20] "[...] unfortunately she does not list the 32 'instrumental or orchestral sequences from the Baroque, Classical, Romantic, or early twentieth century repertoires' (DELIÈGE, 1987: 334) she chose for her experiment number 1 (MESQUITA, 2016, p. 74).

The excerpt below is brought by Mesquita (2016) as an example of juxtaposition, defined by the author as the most characteristic strategy of sound projection in time of Western tonal music. In the eighth measure of this Sonata, Beethoven "begins a new accompaniment in the left hand [and thus] anticipates the accompaniment of the transition, which starts in measure nine, and confounds momentaneously the listener" (MESQUITA, 2016: 77):

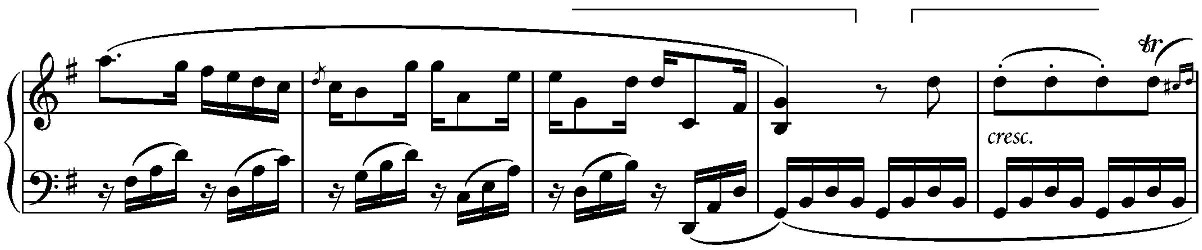

Fig. 3 – Ludwig van Beethoven. *Piano Sonata*, Op. 14, No. 2, 1st mvt., ms. 5-9. Adapted from MESQUITA, Marcos. Segmentation and Juxtaposition: A brief critical survey. *Percepta*, v. 3 (2), p. 69-80, 2016.

"[...] bar lines, which serve to mark off metric units, do not indicate what the rhythmic organization is. Rhythmic groups are not respecters of bar lines. [...] one of the first things that the reader must learn is that the bar line will tell him little about rhythmic grouping" (COOPER and MEYER, 1960: 6). The use of explicit grouping cues in the score is not usual; in addition, our intuitions about it may be inaccurate, preventing a "correct" analysis of a given stimulus (TEMPERLEY, 2001); however, some compositional tools are often used precisely for this purpose: to generate ambiguity.

"Composers [...] can establish articulations in different parameters in different points in time, and blur the perception of sections and subsections, and consequently of the form as a whole" (MESQUITA, 2016: 78). This is a relevant aspect of tonal compositions: "[...] the contrast between sections of very clear phrasing [...] and passages of ambiguous phrasing" (TEMPERLEY, 2001: 65). In this case, the deliberate ambiguity of grouping implies that it is understood in this way, rather than forced to a clear and well-defined pattern (COOPER and MEYER, 1960). In addition to these compositional processes, "grouping can also be [...] emphasized by a performer" (McAULEY, 2010: 185).

Dawe, Platt, and Racine comment that usually the performer's use of cues (phenomenal accents) to mark phrasing lines generates ambiguous transmissions of meter, as these cues no longer mark metric important places. Even so, it is common that "listeners unambiguously perceive the 'correct' metrical structure" (DAWE; PLATT; RACINE, 1993: 796). This may be a perceptual evidence of a widely accepted theoretical conception: that of meter and grouping as distinct structural components, both important for the overall perception of rhythmic structure. Finally, we can conclude that rhythm –

in a less restricted conception – is the interaction between meter and grouping (LERDAHL and JACKENDOFF, 1983; DAWE; PLATT; RACINE, 1993; THOMPSON, 2015).

REFERENCES

BERRY, Wallace. *Structural Functions in Music.* 2. ed. New York: Dover Publications, 1987.

CIRELLI, Laura K.; SPINELLI, Christina; NOZARADAN, Sylvie; TRAINOR, Laurel J. Measuring Neural Entrainment to Beat and Meter in Infants: Effects of Music Background. *Front. Neurosci,* v. 10 (229), p. 1-11, 2016.

CLARKE, Eric F. *Rhythm and timing in music.* In: DEUTSCH, Diana (Org.). *The Psychology of Music.* 2. ed. Chap. 13. p. 473-500. San Diego: Elsevier, 1999.

COOPER, Grosvenor W.; MEYER, Leonard B. *The Rhythmic Structure of Music.* Chicago/London: The University of Chicago Press, 1960.

DAWE, Lloyd A.; PLAT, John R.; RACINE, Ronald J. Harmonic accents in inference of metrical structure and perception of rhythm patterns. *Attention, Perception & Psychophysics,* v. 54 (6), p. 794-807, 1993.

DELIÈGE, Irene. Grouping Conditions in Listening to Music: An Approach to Lerdahl & Jackendoff's Grouping Preference Rules. *Music Perception: An Interdisciplinary Journal*, v. 4 (4), p. 325-359, 1987.

DESAIN, Peter; HONING, Henkjan. The formation of rhythmic categories and metric priming. *Perception,* v. 32 (3), p. 341-365, 2003.

DEUTSCH, Diana. Grouping Mechanisms in Music. In: DEUTSCH, Diana (Ed.). *The Psychology of Music.* 3 ed. Chap. 6. p. 183-248. Amsterdam: Academic Press, 2013.

ECK, Douglas. A Positive-Evidence Model for Rhythmical Beat Induction. *Journal of New Music Research*, v. 30(2), p. 187-200, 2001.

FRAISSE, Paul. *Psicología del ritmo.* Tradução de: Dolores Blasco. Madrid: Ediciones Morata, 1976.

FRANKLAND, Bradley W.; COHEN, Annabel J. Parsing of Melody: Quantification and Testing of the Local Grouping Rules of Lerdahl and Jackendoff's *A Generative Theory of Tonal Music. Music Perception*, v. 21 (4), p. 499-543, 2004.

HAMAOUI, Kamil; DEUTSCH, Diana. *The perceptual grouping of musical sequences*: Pitch and timing as competing cues. In: S. M. Demorest et al. (Eds.), *Proceedings of the 11th International Conference on Music Perception and Cognition.* Seattle: ICMPC, p. 81–87, 2010.

HANNON, Erin E.; TREHUB, Sandra E. Metrical Categories in Infancy and Adulthood. *Psychological Science*, v. 16(1), p. 48-55, 2005.

HASTY, Christopher F. *Meter as Rhythm.* New York: Oxford University Press, 1997.

HONING, Henkjan. *Structure and Interpretation of Rhythm in Music.* In: DEUTSCH, Diana (Org.). *The Psychology of Music.* 3. ed. Chap. 9. p. 369-404. San Diego: Elsevier, 2013.

HURON, David. *Sweet Anticipation:* Music and the Psychology of Expectation. Cambridge: MIT Press, 2006.

IVERSEN, John R.; PATEL, Aniruddh D.; OHGUSHI, Kengo. Perception of rhythmic grouping depends on auditory experience. *Acoustical Society of America*, v. 124(4), p. 2263-2271, 2008.

JONES, Mari R. *Musical Time*. In: HALLAM, Susan; CROSS, Ian; THAUT, Michael (Ed.). *The Oxford Handbook of Music Psychology*. Chap. 8. p. 81-92. Oxford: Oxford University Press, 2009.

KARPINSKI, Gary S. *Aural Skills Acquisition:* The Development of Listening, Reading, and Performing Skills in College-Level Musicians. Oxford: Oxford University Press, 2000.

KRAMER, Jonathan D. *The Time of Music*: New Meanings, New Temporalities, New Listening Strategies. New York/London: Schirmer/Macmillan, 1988.

LARGE, Edward W.; KOLEN, John F. Resonance and the Perception of Musical Meter. *Connection Science*, v. 6(2-3), p. 177-208, 1994.

LERDAHL, Fred; JACKENDOFF, Ray S. *A Generative Theory of Tonal Music*. Cambridge/London: MIT Press, 1983.

LONDON, Justin. *Hearing in Time:* Psychological Aspects of Musical Meter. Oxford: Oxford University Press, 2012.

McAULEY, J. Devin. *Tempo and Rhythm*. In: JONES, Mari R.; FAY, Richard R.; POPPER, Arthur N. (Ed.). *Springer Handbook of Auditory Research:* Music Perception. Chap. 6. p. 165-199. New York: Springer, 2010.

MESQUITA, Marcos. Segmentation and Juxtaposition: A brief critical survey. *Percepta*, v. 3 (2), p. 69-80, 2016.

NOORDEN, Leon; DIRK, Moelants. Resonance in the Perception of Musical Pulse. *Journal of New Music Research*, v. 28(1), p. 43-66, 1999.

NOZARADAN, Sylvie; PERETZ, Isabelle; MISSAL, Marcus; MOURAUX, André. Tagging the Neuronal Entrainment to Beat and Meter. *Journal Of Neuroscience,* v. 31(28), p. 10234-10240, 2011.

NOZARADAN, Sylvie. Exploring how musical rhythm entrains brain activity with electroencephalogram frequency-tagging. *Philosophical Transactions Of The Royal Society B: Biological Sciences*, v. 369 (1658), p. 20130393-20130393, 2014.

PALMER, Caroline; KRUMHANSL, Carol L. Mental Representations for Musical Meter. *Journal Of Experimental Psychology: Human Perception And Performance*. v. 16 (4), p. 728-741, 1990.

PARNCUTT, Richard. A Perceptual Model of Pulse Salience and Metrical Accent in Musical Rhythms. *Music Perception*, v. 11(4), p. 409-464, 1994.

PATEL, Aniruddh D. *Music, Language, and the Brain*. Oxford: Oxford University Press, 2008.

PATEL, Aniruddh D.; IVERSEN, John R. The evolutionary neuroscience of musical beat perception: the Action Simulation for Auditory Prediction (ASAP) hypothesis. *Frontiers in Systems Neuroscience*, v. 8(57), p. 1-14, 2014.

PATEL, Aniruddh D.; PERETZ, Isabelle; TRAMO, Mark; LABREQUE, Raymonde. Processing Prosodic and Music Patterns: A Neuropsychological Investigation. *Brain and language*, v. 61, p. 123-144, 1998.

SAKAI, Katsuyuki; HIKOSAKA, Okihide; MIYAUCHI, Satoru; TAKINO, Ryousuke; TAMADA, Tomoe; IWATA, Nobue K.; NIELSEN, Mathew. Neural Representation of a Rhythm Depends on Its Interval Ratio. *The Journal of Neuroscience*, v. 19(22), p. 10074-10081, 1999.

TAN, Siu-Lan; PFORDRESHER, Peter; HARRÉ, Rom. *Psychology of Music*: from sound to significance. Hove/New York: Psychology Press, 2010.

TEMPERLEY, David. *The Cognition of Basic Musical Structures*. Cambridge/London: MIT Press, 2001.

THOMPSON, William F. *Music, Thought, and Feeling*: Understanding the Psychology of Music. 2. ed. New York/Oxford: Oxford University Press, 2015.

THOMPSON, William F.; SCHELLENBERG, E. G. *Listening to Music*. In: COLWELL, Richard (Ed.). *MENC Handbook of Musical Cognition and Development*. Chap. 3. p. 72-123. Oxford: Oxford University Press, 2006.

TODD, Neil P. The auditory "Primal Sketch": A multiscale model of rhythmic perception. *Journal of New Music Research*, London, v. 23 (1), p. 25-70, 1994.

ZARCO, W.; MERCHANT, H.; PRADO, L.; MENDEZ, J. C. (2009). Subsecond timing in primates: comparison of interval production between human subjects and rhesus monkeys. *J. Neurophysiol.* v.102, p. 3191–3202, 2009.