Entrainment with Music Without Pulse: Cognitive and Psychophysiological Approaches

Thesis · August 2012

DOI: 10.13140/RG.2.1.4448.4968

Entrainment with Music Without Pulse:

Cognitive and Psychophysiological Approaches.

M. Isabel Gutiérrez-Blasco

Registration Number: 110146153

SUPERVISOR: Renee Timmers

Dissertation

Submitted in Partial Fulfilment of the Requirements for

the Degree of Master of Arts in the Psychology of Music

Department of Music

The University of Sheffield

August 2012

Author Note

I would like to thank Renee Timmers for her guidance, support and patience, especially with my language difficulties. This research has not been possible without her wise advices.

I would like to thank the Education Ministry of Andalucía for awarding me with a study license for a year. Without this license, I could carry out neither the MA in Psychology of Music, nor this research. I would also like to thank Banco Santander for awarding me with a Formula Scholarship in order to study this Master's degree. I would like thank to all those who have participated and helped in this research, especially to Theresa Veltri for her help with my English.

I would like to thank my piano professor Ana Guijarro Malagón. I owe her my dignity as a musician and pianist, and meeting Frédéric Gévers. I would like to thank the lectures of Musicology in the University of Granada for opening to me areas of music that I did not know o in Conservatories.

I would like thank my parents and sister for their support, help and love. I would like thank Margarida Olivé Masdeu for all our conversations during this year.

If you find this research interesting, and you have any question or comments, I would be grateful if you get in contact to me (isabel.gutierrez.blasco@gmail).

Table of Contents

List of Tables

List of Figures

Abstract

For biological and social sciences, entrainment is a rhythmically coordinated response to the perception of a rhythmic signal. Musical research has based musical entrainment on pulse periodicity. Both existence of ametrical music (i.e. without pulse), and the existence of entrainment phenomena which are not based on temporal periodicity, challenge this assumption. The present research examines if listeners can entrain with ametrical music. Experiment 1. Listeners' reaction times (RTs) to changes of timbre in Messiaen's ametrical melodies and their metrical transformations were recorded. A significant effect of *tempo* was found (fast music elicited faster reactions), suggesting that ametrical music can induce cognitive entrainment. Expectancies, instead of periodicity, could explain this finding. In Experiment 2 listeners' psychophysiological responses (heart and respiration rates, skin conductance and temperature) to 4 musical *stimuli* (2 slow and 2 fast; all lasted 3 min.) composed by Messiaen (ametrical) and Beethoven (metrical). Participants estimated their duration, and rated variables which could influence their experience. Significant effects due to process were found in RR and SC. Listeners' RR and SC decreased in listening to all musical *stimuli*, indicating a progressive relaxation. Participants' subjective data did not revealed significant differences in the perception of metrical and ametrical music. I suggest a framework to study the effects of music based on entrainment, the musical analysis of tracks employed in present and previous research, and music therapy applications. There could be three main types of reactions to music: contemplation, movement and communication. Theoretical and practical implications could be derived from this theory.

Keywords: entrainment, ametrical music, pulse, periodicity/aperiodicity, expectancy, reaction times, psychophysiological responses.

Entrainment with Music Without Pulse: Cognitive and Psychophysiological Approaches

> Symmetry breaking separates things, leading to differences and individuation, whereas entrainment creates order and harmony, bringing things together into interacting wholes. Together, the two are behind much organisation, from galaxies through living things to recurring chemical processes (Collier and Muller, 1998; as cited in Collier, Burch, Box, & City, 2000, p. 1-2).

Entrainment, in a broad sense, is “a phenomenon in which two or more independent rhythmic processes synchronize with each other” (Clayton, Sager, & Will, 2005, p. 1). This concept has been applied to describe numerous physical and biological systems, which show a tendency originated by interaction to coordinate temporally structured events (Clayton et al., 2005, p. 3). Human beings, as a result of our capacity to respond to perceived rhythmic signals, are able to become entrained with each other or with external stimuli (Phillips-Silver, Aktipis, & Bryant, 2010). This is why entrainment has become a useful concept in various domains of social sciences research (as for instance in verbal and gestural communication), and, naturally, in the investigation of music, a perfect archetype of entrainment.

Entrainment has been applied to the study of different musical phenomena: the interaction between musicians; the musical interaction between musicians and audience; the interaction between music and biological rhythms (as respiration, blood circulation, heartbeat, brain waves, etc.); the relations between rhythm and body movement and/or musical gestures; and the perception, attention, and expectations of rhythmic processes. Most of the research about entrainment in music refers to pulse synchronization, meter, and metrical perception (e.g.: Large & Kolen, 1994; Merker, Madison, & Eckerdal, 2009). This research is the result of the development of the dynamic attending theory created by Jones and her collaborators (Clayton et al., 2005). Most of the work has been focused on the idea of temporal periodicity in music: a sense of pulse and a hierarchical meter.

It could seem obvious to consider beat and meter the key of musical entrainment from the perspective of present Western culture. Nonetheless, there is music from diverse historical periods and geographical origins, which are not based on temporal periodicity. As Justin London points out, “Musical traditions reflect the different temporal sensibilities of their respective ages” (London, 2012, Rhythm, §III: Current rhythm research, para. 33). A “dramatic change” occurred around 1600 which created the modern foundations of Western music. Binary relationships for normative durations, bar-lines, ties and tempo terms were introduced to notation during this period (London, 2012, Rhythm, §II: Historical studies of rhythm, para. 18). Metrical structure was established, and has remained. Nonetheless, the conception of metrical structure has been defied in 20th century by some composers, such as Olivier Messiaen. He found inspiration for his free rhythms in Gregorian chant, in Indian rāga and in nature, particularly in birds’ singing (Griffiths, 2012; Messiaen, 1956).

Various ethnomusicologists, such as Kouwenhoven (2004), have noted that the applications of entrainment in music have been considered only in Western metrical music. He reminds us that nonmeasured exists in music in African and Asian cultures. Furthermore, he defends the temporal coherence of these types of music. On the other hand, Barnes and Jones (2000) explain that entrainment can be a flexible process that has the capacity to adapt to the levels of rhythmic complexity and coherence which can be found in the real world. They explicate that listener might entrain even when music does not show an explicit pulse. Jones, in an extensive review, points out that there are very few studies which researched with contexts where rhythm and rate vary (2004, p. 77). Yee, Holleran, and Jones, (1994), Jones and Yee, (1997), Large, E., Jones (1999), Barnes & Jones (2000)and Pashler (2001) experimented with non- musical *stimuli*. Jones & Boltz, (1989) experimented with three metrical folk tunes. They modified the position of the harmonic accents in some versions, locating them in weak metrical positions. I could not found any research with musical *stimuli* without pulse and/or metre, nor with complex or additive metres. Even complex or additive metres entail a periodic temporal structure. Moelants (2006) in his analysis of *aksak* metres found that they can be understood as “expressive transformations of regular metres” (p. 167). Therefore, research using musical *stimuli* without pulse should be carried out in order to test if entrainment is a process flexible enough to adapt to rhythms of the real world.

Music research works with a conception of entrainment based on periodicity, which does not explain the non-periodic temporal components of music. Clarke (2004) alerts of the necessity to distinguish between periodic and non-periodic components of music in the research of musical entrainment. In his opinion, the dimensions of music which have aperiodic elements may not be enlightened with the entrainment principle. Therefore, the common critique to the application of entrainment in music research is how this concept can deal with temporal aperiodicity.

The investigation of entrainment in other domains is not based in periodicity. As (Cummins, 2009) says, "the world is not a clockwork toy" (p. 21). Evident examples of entrainment can be found in the relative coordination and changing influence of weak coupling of groups as swarms of birds and bees, shoals of fish, and herds of certain herbivores (Deutsch, 1996; as cited in Cummins, 2009), and speech (Cummins, 2009). Like speech, music is composed by numerous elements, however, only pulse has been studied as the unique possible originator of entrainment in music (e.g.: Merker et al., 2009). At least, three consequences have been derived from this assumption:

- The possibility that ametrical and unmeasured music might entail entrainment has been not researched. Albeit Merker and his collaborators (2009, p. 8) state that the only rhythmic music is measured music, as London (2012) points out, all music entails some kind of rhythm. Psychologically, "rhythm involves the structure of the 'temporal *stimulus*'" (London, 2012, Rhythm, §I: Fundamental concepts & terminology, para. 3). In addition, as it has been aforementioned, ethnomusicologists who have studied examples of unmeasured music defend its temporal coherence.
- No other musical element has been studied as a possible contributor to entrainment.
- The aperiodical components of music have been considered incomprehensible as a result of the entrainment principle.

However, Jones' (1976) rhythmic theory studied and postulated entrainment in aperiodical contexts such as speech. In her theory periodicity was not indispensable for entrainment. She suggests the existence of two stages in the synchronizing process (pp. 340-341): firstly, priming and expectancy; secondly, recruitment and synchronization (the perception of auditory inputs in real time which leads to the synchronization between perceptual rhythms and pattern structure). The first stage, priming, is based on expectancies about “where” and “when” an event will occur. Therefore, temporal expectancy is part of the entrainment process. Despite in research on musical entrainment this phenomenon has been rooted in temporal periodicity, the first step in the entrainment process, according to Jones’ theory, is expectancy, not temporal periodicity. Assuming that pulse and metre, i.e., temporal periodicity, is what allows entrainment has become an obstacle in the research of musical entrainment. This assumption had impeded to investigate entrainment with ametrical and non- measured music, and the investigation of the aperiodic components of musical experiences. In addition, it has been an obstacle to insert musical entrainment in broad research frameworks about entrainment in social and biological sciences.

The aim of the present study is to research if listeners can entrain with ametrical music. Two processes of entrainment in listening to music have been investigated. They occur at the same time and are interconnected: first, the processes of perception, attention and expectations; and second, the psychophysiological responses to music (heart and respiration rates, skin conductance and temperature). I have also questioned in this research if any difference arises in subjective perception of time in listening to metrical and ametrical music. With this purpose, two experiments have been carried out using Beethoven’s metrical music and Messiaen’s ametrical music. The next section provides the context for this research.

First, a framework for the investigation of entrainment in biological and social sciences is explained. My research tries to provide experimental evidence of one of the conflicting issues of this framework: how is entrainment possible in contexts which do not show temporal periodicities, in particular with ametrical music. Second, the basis of entrainment from the point of view of cognitive psychology is expounded: Jones’ rhythmic theory, her model of entrainment and her dynamic attending theory. Third, the differences in listening to metrical and ametrical music could involve differences in how attentional resources are administered. Attention and subjective perception of time have been related by some researchers. Furthermore, the findings which might support the idea that composers could manipulate the subjective perception of time using different types of rhythmic structures are exposed. Finally, previous research on how psychophysiological responses to music have been investigated from the perspective of entrainment will be reviewed. The next section also contains my hypothesis about the phenomenon of entrainment in listening to ametrical music from the aforementioned perspectives.

1. Literature review

1.1. Entrainment

The idea that musical entrainment is only possible thanks to pulse, is so pervasive that it is part of many definitions of this concept. For example, Clayton *et al.* (2005) define entrainment as “the coordination in time of one participant's behaviours with those of another and involves the organization of the perception and behaviour of participants around temporal regularities that are inferred from musical sounds and actions in the form of a periodic pulse or beat that is sensed by all participants” (p.6). Their paper is an excellent introduction to this topic. Their exposition includes a short history of this concept: since it was identified by Huygens, to its application to diverse scientific domains. Entrainment was a challenge for physics and mathematics because it entails dealing with non-linear systems. Whereas in linear systems the changes in one variable can be predicted in a dependent variable, in non-linear systems the changes in one variable produce inconsistent changes in a dependent variable. Classical physics works with these types of systems linearizing them, that is, describing a limited range of their behaviour by linear equations. Nonetheless, it has been demonstrated that the differences between linear and non-linear systems are too big to understand the later ones as a composition of the former ones. In addition, it has become obvious that non-linear systems are the most common in the world (Clayton, *et al.*, 2005).

In sum, entrainment between systems only eventually concludes in their synchronization in period and phase. Nevertheless, generally in music research it has been usually considered that only this result can be named entrainment, i.e., only the synchronization with a periodic pulse can be considered entrainment. A paradoxical example, considering their complete overview of this concept, is the aforementioned definition created by Clayton and his colleagues. An important exception is Stevens' and Byron's explanation of entrainment (2009), who remark that entrainment ends only eventually in the locking of a common phase and/or periodicity.

The necessity of a common framework has become more evident as entrainment has been applied to diverse scientific domains. Phillips-Silver, Aktipis, and Bryant (2010) proposed a unified theory valid across biological and social sciences, and an operational definition of this concept: "spatiotemporal coordination resulting from rhythmic responsiveness to a perceived rhythmic signal" (p. 5). The ability to detect and adapt to ecological rhythm provides evolutionary advantages, especially when this information is the output of other organism's respiration, locomotion, and feeding. This is why these authors do not limit entrainment to the perception of auditory *stimuli* and include any type of signal which can produce rhythm. According to their framework, there are three building blocks which allow the capacity for entrainment. Each of them is based in the next abilities:

- The detection of rhythmic signals.
- The production of rhythmic signals. Examples of rhythmic signals can be respiration or heart rate, and also signals generated to communicate with others.
- The integration of sensory information and motor production to adjust the motor output to the rhythmic input.

Music is a complex phenomenon in which it can be observed self-entrainment (in solitary music production), and also social or interpersonal entrainment (Clayton et al., 2005). Phillips-Silver *et al.*(2010) distinguish two types of the later:

- Mutual social entrainment: two individuals interact between them responding to the rhythmic output of the other.

- Collective social entrainment: a rhythmical interaction between the members of a group in a network of inputs and outputs.

This framework helps to understand the evolutionary advantages of entrainment to living organisms. It also places music in an ecological context, and therefore it suggests that music entrainment is not only limited to auditory information. Music is fundamentally an audio-visually integrated activity, albeit the invention of technologies of sound recording and playback in the last century has allowed isolating the sonic components from the visual aspects of music. Musicians use facial expressions, body language, and eye contact, in addition to musical cues, in order to coordinate with others (Seddon & Biasutti, 2009). Gestures, and movements are also important in how audiences perceive musical performances (Thompson & Graham, 2005). In addition, it is highlighted that there are other activities, such as verbal and gestural communication, which elicit entrainment without the necessity of periodicity.

This framework helps to integrate the research about entrainment from different domains (cognitive psychology, music psychology, ethnomusicology, and other social sciences among others). The framework designed by Phillips-Silver *et al*. also overcomes an important Kouwenhoven's (2004) reproach. He criticizes Clayton and his collaborators for introducing "entrainment almost as a kind of container notion, incorporating all or much of what we might possibly want it to be". The phenomenon of interaction between rhythms processes of mechanical systems (as for example Huygens's pendulums) is transferred to biological and social sciences in this framework. Living beings obtain adaptive advantages if they can detect rhythmic information in their environments and can react to them. An adaption can be just a change in their respiration and heartbeat, to move in a specific fashion, or to communicate with others. Verbal communication, music and dance are probably the most complex examples of entrainment. This framework proposes that all of them have got a common origin. Nevertheless, there is still an issue which impedes the establishment of a connection between them. Music research examining entrainment explains this phenomenon thanks to the periodicity of pulse, whereas most ecological events and verbal and gestural communication do not normally show this periodicity. This obstacle could be overcome if entrainment with music without the periodicity of the pulse can be demonstrated. This is the aim of the current research.

1.2. The Detection of Rhythmic Signals: Attentional Entrainment

Studying the perception of rhythmic signals entails studying the mechanisms for perceiving time. After several decades of research, scientists from different domains (mainly from cognitive and social psychology and neurology) have developed a considerable number of theories and models of timing. They can be divided into two main types: those which do not involve the idea of an internal clock and describe time perception thanks to cognitive mechanisms, and those which consider that an internal clock is responsible for estimating time. This later group of theories has a longer tradition and they have developed two different perspectives. From the linear perspective, temporal control is explained by the pacemaker-counter process; whereas from the non-linear perspective, time control is achieved thanks to the oscillator process (for a review: Grondin, 2010; 2001). Grondin (2001) suggests that more than one central timekeeper could contribute to the perception of time. On the other hand, for understanding the perception of temporal intervals which form part of sequences of signals (as in many real-world events happens, like music, speech or coordinated movements), oscillator models are better equipped (Jones & McAuley, 2005; Grondin, 2010).

Among oscillator models the one that stands out is the entrainment model proposed by Jones, (1976) as part of her rhythmic theory for describing the perception, attention, and memory in human listening. It was conceived as a reaction to the approaches to speech perception which neglected the relationships between pitch and time in pattern structures, and to psychological research which does not take into account temporal factors. The fundamental idea of her entrainment model is that “perceptual rhythms can become synchronized with world time structure” (p. 347). This is possible thanks to the interrelation between attention, expectancy, and learning. The psychological mechanism which relates them is named by Jones “nested rhythms” (1976). It is important to explain certain of the assumptions in which this theory is grounded, in order to understand the meaning of the “nested rhythms”. These are two basic assumptions of her theory:

- "Patterns in the physical world (world patterns) consist of energy changes defined within three space dimensions and a time dimension. All dimensions are most simply conceived as having nested, or hierarchical, structure" (p. 328).
- "World patterns can be represented by the human perceiver in terms of relations on a finite number of subjective dimensions. Each subjective dimension bears a more or less direct psychophysical correspondence to a world dimension" (p. 328).

Jones bases these assumptions in research about the existence of subjective pitch, loudness, and time scales. In particular, the main concern in her presentation of this theory was to justify the existence of subjective time scales which allow to a perceiver to respond to timed relationships. These time scales permit to incorporate time as one of the dimensions of serial patterns structures (1981). Hence, "changes along other dimensions must be proportional to changes along the time the time axis" (Jones, 1976, p. 339),and therefore, time should be considered as part of the definition of *stimulus* structure.

Another important assumption of the general theory is that "all moving things have a time structure" (Jones, 1976, p.340). The biological rhythms of organisms represent this time structure and provide a time scale for the analysis of world patterns. Each rhythm could correlate with certain world patterns depending on their time periods: fast rhythms entrain with periods of micropatterns, whereas slow rhythms entrain with periods of macropatterns. Therefore, "a set of rhythms, graded in periods, responds to world structure" (Jones, 1976, p. 340).

The framework of this rhythmic theory, in which Jones proposed the entrainment model, was the basis for the evolution of her dynamic attending theory (e.g.: Jones, 1987; 1992; 2004; Large & Jones, 1999; McAuley, Jones, Holub, Johnston, & Miller, 2006) and her metric binding hypothesis (Jones, 2009). The dynamic attending theory (DAT) can be understood as an oscillatory process composed by a nonlinear oscillator and an attentional energy rhythm. The responses to complex rhythms may be understood thanks to a multiple-oscillation model. It entails the coordination among internal attending oscillators (Large & Jones, 1999). The attentional oscillators fluctuate in order to adapt attentional rhythms to the perceived rhythms. Therefore, the mechanics of entrainment in human cognition, according this theory, have got three primary stages:

1) Perception: the listener, from acoustical cues of the music, forms expectations.

When expectations accomplish:

2) Synchronization is produced.

When expectations do not accomplish:

3) An adjustment or assimilation is produced.

Normally, pulse is the time referent level for listeners. They can shift attention from one level to other in the hierarchical metrical structure. When music meets the expectations of the listener, which are created by pulse or any metrical level, then perception accuracy is enhanced. The listener's temporal focus narrows when sequences contain rhythmically regular timing. Whereas in rhythmically irregular sequences the attentional focus widens (Jones, Johnston, & Puente, 2006). As Clayton points out (2005), Jones and her colleagues show with their work that entrainment can be a flexible process "that can adapt and accommodate many ranges of rhythmic complexity and coherence found in the real world" (p. 15).

Jones and Boltz (1989) distinguish between temporally coherent, or hierarchical time structures, and temporally incoherent, or non-hierarchical ones. The difference between them relies on the distribution of the non-temporal information. In hierarchical structures the non-temporal information is distributed forming regular, ratio-based "temporal nestings". Whereas in non-hierarchical ones "nesting" is more irregular and less connected. In western music, time hierarchy is provided by meter. Meter is a "time frame from which rhythm and tempo deviate on artful temporal journeys" (p. 467). As it has already been mentioned in the introduction, Barnes and Jones, (2000) explain that listeners might entrain even when music has not explicit pulse. According to their theory of "centering" listener may perceive a "centered" or median period length in the music and entrain to it, i.e. it is produced an adjustment or assimilation (Jones & Boltz, 1989). Nevertheless, most research has been carried out with non-musical *stimuli*. When experiments were conducted with musical rhythms, they were part of a metrical structure, as it has been explained in the introduction). These kinds of rhythms were not really non-hierarchical, because listener can obtained their metre from the melody thanks to diverse musical cues, as melodic or dynamic accents. This phenomenon is explained by the last Jones' theory (2009): the metric binding hypothesis. It maintains that: "whenever two or more neural oscillations are simultaneously active, over time their internal entrainments lead to binding and formation of a metric cluster" (p. 84). Jones attributes this phenomenon to training and enculturation. Once acquired these metric clusters, listeners can "activate oscillators for unmarked metric levels" (p. 85). Therefore, it has not been tested experimentally if ametrical music could induce entrainment.

In sum, Jones' rhythmic theory (1976) predicts that entrainment with ametrical music is possible. DAT explains that the accomplishment of expectations is the key for synchronization. Temporal periodicity enhances temporal predictability, although it is not the only source of expectancy. Other musical cues might contribute to generate expectations, and therefore to cause entrainment. DAT has been tested with isochronous and unison sequences, and with metrical rhythms. Therefore, the next step in the research is experiment with ametrical rhythms.

1.3. Attention and Estimation of Time.

Clarke and Krumhansl (1990, pp. 220–221) pointed out the lack of attempts in contrasting theories of time perception and the experience of time in music, and the lack of empirical research about the perception of longer duration in music. They carried out experimental research about the perception of the duration of Stockhausen's and Mozart's musical excerpts from 20 to 40 seconds approximately. Participants, all musicians, were very accurate in identifying the relative duration of the musical fragments. The differences in musical style and structure did not seem to influence participants' accuracy to distinguish relative durations. These researchers speculated about the type of perceptual strategies adopted by the participants. They suggested that the perception of longer durations than the rhythmic units could be better explained by information processing models than the clock or pacemaker models.

On the other hand, Jones (1976) considered that "Time estimation can only be evaluated in terms of the interaction of a listener's attentional level with the multidimensional structure of patterns used to present time intervals" (p. 352). The dynamics attending theory differentiates between two modes of attending: one focused on present, that Jones name "analytic attending", and the other projected in future, and called "future-oriented attending" (Drake, Jones, & Baruch, 2000; Jones, 2004; Jones & Boltz, 1989; Jones, Moynihan, MacKenzie, & Puente, 2002). Future-oriented attending allows to address attention to higher referent levels, and therefore, to wide temporal spaces. Thus, this type of attention facilitates anticipatory behaviours. Whereas analytic attending concentrates attention on narrow temporal spaces in order to understand the structure of small groups. Individuals can shift from one mode of attention to other in order to accomplish different aims (Jones & Boltz, 1989).

Jones suggests that "an important and basic aspect of communication involves the way any musical or linguistic interaction effectively controls the attending of the parties involved and in so doing establishes for them a shared perspective from which to assess the event itself" (1992, p. 91). She proposes that the hierarchical metrical structure of western tonal music creates a time structure which controls attending (1992). On the other hand, some composers of 20th century, as Claude Debussy, and especially Olivier Messiaen, created melodies which deliberately erased the sensation of an inherent beat and a metrical structure. They manipulated the durations of notes to achieve a different perception of musical time. The listening of this particular music entails a different experience than the listening of music with pulse.

Music involves all aspects of time (Large & Kolen, 1994): "It may even be that composers and performers shape the temporal structure of music to reflect and to explore natural modes of temporal organization in the human nervous system" (Large & Kolen, 1994, p. 202). Pulse and metrical structure could reflect a natural mode of temporal organization and these could explain how traditional western music entrains with our endogenous rhythms. Contrariwise, the music of composers who do not follow those structures in their music could reflect other natural modes of temporal organization. In the music of Olivier Messiaen bars, when they are marked, have different durations. The smallest rhythmic figure is used only to allow musicians to achieve accuracy during practice. Albeit musicians have to practice having like objective to perform Messiaen's free rhythms without counting and marking this reference rhythmic figure. Therefore, there is no a framework which imposes (implicitly or explicitly) a periodic and hierarchical metrical structure (Messiaen, 1956). Messiaen is considered as one of the main western composers of the last century. His music is pleasant for many people although it is not based on periodicity. As Paul Griffith (2012) points out:

> Where a conventional Western composition will seem to unfold as a thread through time, Messiaen's discontinuous music rather provides an environment within which time itself can be observed, 'coloured', as he would say, by rhythm: time suspended, in his slow movements, or time racing forwards, in his scherzos and dances, or, most frequently, time changing its rhythmic colour from moment to moment. Instead of affirming the orderly flow of everyday existence, this is music which acknowledges only two essences: the instantaneous and the eternal (para. 21).

Jones states that "a musical event, reflects an artist's attempt to control the point of view or perspective of a listener" (1992, p. 91). Shifting between perspectives, i.e., between different levels of attending, is more difficult when music has a low temporal coherence (Jones & Boltz, 1989), that is, in ametrical or not very strongly metered music. In these situations, listeners use analytical attention. Whether listeners can not apply future-oriented attending, thanks to the artifices of a composer, attention is completely focused in the current sound, and all its subtleties of timbre, pitch and dynamics. When attention is completely focused in present, instant becomes eternal. The influence of attentional resources in time perception has been demonstrated with multiple types of experiments (Grondin, 2010, p. 516). Therefore, the estimated duration of Messiaen's music could be longer than western metrical music of the same duration. This hypothesis will be tested in the second experiment of this research. Other factors, such as: emotions; motivation or pleasure (Grondin, 2010); mental workload depending on the complexity (Ornstein, 1969), and/or familiarity with music (Clarke & Krumhansl, 1990); dynamism; and absorption in listening to music (Brown & Boltz, 2002; Clarke, 1987; Clarke &

Krumhansl, 1990) could influence the estimated duration of music, therefore they will be included as variables in the experiment.

1.4. Entrainment and Psychophysiological Responses to Music

Jones claims that her theory "is more closely tied to potentially measurable biological phenomena than are some information processing models" (1976, p. 340). According the assumptions of her theory, organisms have a time structure, composed by nested time zones which are reflected in an array of biological rhythms. In particular, "The human system in general and the perceptual system in particular depend upon the properties of endogenous rhythmic processes in the nervous system" (Jones, 1976, p. 328). The entrainment model suggests that endogenous internal rhythms entrain with musical rhythms. Research has been conducted in order to test if endogenous internal rhythms entrain with the music, although it has not been demonstrated unequivocally if this phenomenon exists. Even the findings about the psychophysiological responses to music are contradictory (for reviews see: Hodges, 2009; 2010). New technologies in the last three decades have allowed improving the investigation of entrainment in this area. Some research shows results which add evidence to the possible existence of this phenomenon, such as the studies carried out by Nozaradan, Peretz, Missal, and Mouraux (2011) about neural entrainment; Bernardi, Porta, Casucci, Balsamo, Bernardi, Fogari, and Sleight (2009), and Etzel, Johnsen, Dickerson, Tranel, and Adolphs (2006) about entrainment between musical rhythms and cardiovascular/respiratory responses and cerebral rhythms.

Part of the investigations has been carried out in the field of music therapy in order to improve the applications of music with therapeutic aims (Bradt, 2010; Chan, Chung, Chung, & Lee, 2009; Dainow, 1977; Ellis, Koenig, & Thayer, 2012; Iwanaga, 1995; Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008; Lee, Chung, Chan, & Chan, 2005; Rider, 1985; Rider, Floyd, & Kirkpatrick, 1985; Thaut & Gerald, 2010; Thaut, 2005; Thaut, Kenyon, Schauer, McIntosh, 1999). Other investigations have been done with the purpose of finding out which psychophysiological responses (changes in HR, RR, SC and temperature) music produces, and understand the mechanisms by which the human body entrains to music (e.g.: Bernardi, Porta, & Sleight, 2006; Möckel, Röcker, Störk, Vollert, Danne, Eichstädt, Müller, Hochrein, 1994; Bernardi et al., 2009; Haas, Distenfeld, & Axen, 1986; Yamamoto & Miyake, 2000).

Some research has focused on the entrainment between music and body movement, in some cases with the purpose of using rhythm in sensorimotor rehabilitation (Large & Jones, 2000; G. Madison, 2006; Guy Madison, Gouyon, Ullén, & Hörnström, 2011; Mates, Müller, Radil, & Pöppel, 1994; Su & Pöppel, 2011; M. H. Thaut, 2005; Todd, Cousins, & Lee, 2007; L. J. (McMaster, Trainor, 2007; Trainor, Gao, Lei, Lehtovaara, & Harris, 2009; Zentner & Eerola, 2010).

Recently, research has test whether there is neural entrainment to beat and meter. It has been found that beat and metre elicit sustained periodic EEG response tuned to them (Nozaradan *et al*., 2011). In addition, during open brain surgery changes of neural discharge rate were found as a response to all types of music tested. Furthermore, some neurons entrained with a rhythm, and other neurons changed their activity according to musical phrases (Creutzfeldt & Ojemann, 1989).

Jones proposes that in all human performance "An array of rhythms that vary in specific frequency from very slow to very fast provide a time-scale analysis. Each frequency may correlate with a time period within a given world pattern" (1976, p. 340). This implies that biological rhythms can vary its frequency only in a range around their spontaneous frequencies; therefore they can entrain only with rhythms with frequencies in their normal range.   Following these assumptions, endogenous rhythms might entrain with different levels of the rhythmical structure of the music. According to previous studies, with metrical music heart rate (HR) could entrain with pulse (Luciano Bernardi et al., 2009; Iwanaga, 1995) and respiration rate (RR) with bars (Haas *et al.,* 1986; Yamamoto & Miyake, 2000). No experiment has been carried out with ametrical music in this area. The difficulty of looking for entrainment between these endogenous rhythms and ametrical music is due to the lack of periodic structures as pulse and metre which could correlate to heart and RRs. I hypothesize that heart and RRs could entrain with ametrical music, but in a different fashion than a synchronization of frequencies. Music that is strongly rhythmical is used in many situations, as in dance, for inducing movement (e.g.: Madison, 2006; Madison et al., 2011; Merker, Madison, & Eckerdal, 2009; Thaut, 2005). Marked pulse and metre (or standardized dance rhythm) elicit accurate expectations. Body movement could be easily synchronized with marked pulse and metre. On the contrary, music without a clear pulse, as for example plain chant, is not used to induce movement, but a passive attitude such as contemplation or prayer. Responses to these types of music could be a decrease in heart and RR, due to the fact that body does not have to get ready for movement or action.

On the other hand, changes in SC and temperature could reflect mental and emotional reactions to music (Hodges, 2010; Rickard, 2004). I hypothesize that differences in SC could be attributed more to the specific musical pieces and their capacity to move each listener than for being metrical or not. This hypothesis includes metrical and ametrical music.

Temperature could also reflect changes in the perception of time (Wearden, Penton-Voak, 1995). If the rate of subjective time can increase when body temperature increases above normal, and decreases in the opposite situation perhaps, the inverse process could be elicited. If music could induce a decrease in the rate of subjective time, then that could be reflected in a decrease of temperature. On the contrary, if music could induce an increase in the rate of subjective time, that could be reflected in an increase of temperature. Consequently, it could be hypothesized that slow music may decrease body temperature, and fast music increase it. In addition, if ametrical music induces an analytical attending, the subjective perception of time could be slowed down. This slow perception of time could consequently induce a decrease in body temperature.

2. Experiment 1: Attentional Entrainment in Metrical and Ametrical Music

Experiment 1 examined if attentional entrainment is possible in ametrical music. Research on attention traditionally works by measuring a participant's reaction times (RT) to specific *stimuli* in order to determine levels of attention. In this experiment participants had to press a button when an alternative timbre (harp) to the main timbre (piano) of the melody appeared. The differences between both timbres were evident enough to be easily recognizable, but not too contrasting to interrupt the continuity of the melody. I introduced the changes of timbre in two Messiaen's ametrical melodies: one fast and one slow. In addition, I manipulated these melodies in order to adjust them to a periodical hierarchical structure typical of the Western music of the last three centuries. The null hypothesis predicted no effects due to meter or *tempo*, and therefore entrainment is not found. The dynamic attending theory predicts effects due to meter and *tempo*. Entrainment might be reflected in RTs: fast music might elicit shorter RTs than slow music. In addition, DAT and the metric binding hypothesis (Jones, 2009) predict that RTs should be faster in metrical music than in ametrical music.

2.1. Method

2.1.1. Participants. I selected musicians as participants in this research because they probably will entrain with the music faster and more frequently than non-musicians. There are findings which back up this hypothesis. For instance: musicians are better than non-musicians in perceiving emotion in speech (Strait, Kraus, Skoe, & Ashley, 2009); respiratory sensitivity to music is greater in musicians than in non-musicians (L Bernardi *et al*., 2006); musicians extract more relevant information from music on pre-attentive auditory processing (Koelsch, Schröger, & Tervaniemi, 1999). Furthermore, their musical training allows them to perform more accurately on discrimination of timbre tasks (Pantev, Roberts, Schulz, Engelien, & Ross, 2001).

Thirty-seven musicians participated in this experiment. The criterion to consider a person as a musician was to have at least five years of formal musical training or, for autodidacts at least ten years of musical active practice. No effort was made to recruit participants based on sex (18 females, 19 males), age (from 18 to 52, M = 24.62, SD = 7.19), nationality (32 from Western countries and 5 from Eastern countries), handedness (24 right-handed, 13 left-handed) or speciality of musical performance (7 voice; 30 instruments: 11 keyboard, 8 woodwind, 3 brass, 6 bowed strings, and 2 plucked strings). Most participants were students in the Music Department of University of Sheffield. Informed consent was obtained from participants before they took part in the experiments of this research, which was approved by the Ethical Committee of the Department of Music of the University of

Sheffield. All participants filled out a background questionnaire (see Appendix A), which was used to gather information on their musical experience and tastes (Table 1). Seven subjects' data were eliminated because of technical problems in recording all their RTs.

Table 1

Descriptive statistics about the participant's musical experience and tastes

	Min.	Max.	Mean	SD
Years of performing	6	30	14.22	6.72
Years of music lessons	0	30	12.30	6.06
Number of hours listening to music per week	3	45	15.08	10.75
Numbers of hours playing per week	0	40	12.24	8.76
How much they like modern classical music (from 1, "I hate it"; to 7, "I love it")	2	7	4.73	1.56

2.1.2. Stimuli and conditions. In order to experiment with ametrical music I selected as auditory stimuli two melodies from two movements of Messiaen's *Quatuor pour la fin du temps* (1942): *3. Abîme des oiseaux* (Figure 1), and *6. Danse de la fureur, pour les sept trompettes* (Figure 2). Both have neither regular *tactus* or pulse, nor regular metrical structure (Messiaen, 1944, pp. 14-17). Their rhythms were free due to the use of *valeurs ajoutés* (added values): "short value[s], added to any rhythm whatsoever, whether by a note, or by a rest, or by the dot" (Messiaen, 1944, p.16) "which transforms its [rhythm's] metric balance" (Messiaen, 1944, p.15). Messiaen notated these melodies using his first type of notation which consist of writing the values without beat and measure. Bar-lines do not indicate measures, but periods with different durations (Messiaen, 1944, p. 28).

These two melodies have different *tempi*: *Abîme des oiseaux* is slow (*Lent, expressif et triste*), whereas *Danse de la fureur* is fast (*Décidé, vigoureux, granitique, un peu vif*). Messiaen replaced the concepts of "measure" and "pulse" by "the feeling of a short value […] and its free multiplication" (Messiaen, 1944, p.14). The reference value in both melodies where quaver (♪= 44 the former, ♪=176 the later).

I transformed both melodies modifying the duration of the notes with added values in order to adjust them to a metrical structure: 3/4 for the slow melody and 4/4 for the other. I performed and recorded the original melodies and their transformations in a Disklavier YAMAHA DU1E3. I used Cubase 5 software in order to change the timbre of certain notes, from piano to harp. There was one change of timbre each two bars, therefore eight modifications in the slow melody and four in the fast melody. In order to compensate the possible differences in levels of attention when notes were in different positions in metrical bars I made an equal number of changes of timbre in each position. The modifications in the slow melody were: two in the first beats (one of them coinciding with a melodic accent), two in the second beats and two in the third beats. These last changes never coincide with melodic contour accents, i.e., the highest notes of musical phrases and their beginnings. The timbre alterations of the fast melody were: two in the first beats (one of them coinciding with a melodic accent), one in a second beat and one in a third beat (both avoiding notes which were melodic accents). The changes of timbre involved all the notes in the selected beats in order to make it easier to recognize and therefore avoid mistakes. I created three different versions of the slow metrical music with changes of timbre in different notes and six different versions of the fast metrical excerpt. I made an equal number or versions for the original musical fragments with changes of timbre in the same notes compared to the metrical versions[1].

A)

[1] All versions can be consulted in Appendix B, and listened to in the attached CD.

B)

Figure 1. Slow *stimuli*: the original ametrical melody and its metrical transformation. A) Messiaen's *Quatuor pour le fin du temps:* 3. *Abîme des oiseaux*, bars 1-11 (1942). B) Metrical transformation of the same melody. I modified the duration of several notes in order to adjust the rhythm to a 3/4 regular metre.

A)

B)

Figure 2. Fast *stimuli*: the original ametrical melody and its metrical transformation. A) Messiaen's Quatuor pour le fin du temps: 6. *Danse de la fureur, pour les sept trompettes,* bars 1-6, right hand of the piano part (1942). B) Metrical transformation of the same melody. I modified the duration of several notes in order to adjust the rhythm to a 4/4 regular metre.

2.1.3. Equipment. The software system Sonic Visualiser was used to play the auditory stimuli to the participants and to record RT thanks to its feature "New Time Instants Layer". Participants pressed the key ";" each time they listened to the change of timbre. The layer created for each occasion was exported as text. I also employed Sonic Visualiser to obtain the exact points in time of the changes of timbre. The first step was to analyse the musical fragments with the plugin of the

University of London Queen Mary named “Note Onset Detector”. The next step was to eliminate all the lines which corresponded to notes played by a piano in the layer generated. This layer was exported as text file. A Toshiba Satellite R830 laptop was used to carry out this experiment. Participants listened to auditory stimuli with circumaural headphones. Statistical analyses were carried out with IBM SPSS Statistics Version 19.

2.1.4. Design. The experiment was a two-way repeated measures factorial. The dependent variables were meter (levels: metrical and non-metrical) and tempo (levels: slow and fast). The independent variable was the reaction times (RT) of the participants to the changes of timbre measured in seconds with nine decimals. Participants listened to four versions of the fast melody (two of the ametrical original one, and two of the metrical transformation) and to two versions of the slow melody (one of the original and one of the metrical transformation in order to record the same number of reactions times for the four conditions of the experiment.

In order to avoid familiarization I counterbalanced the order of presentations, two series considering the *tempo* of the melodies were used: 1) Fast (F)-Slow (S)-F-F-S-F, and 2) F-F-S-F-S-F. Both series were followed by equal number of participants. The order of the ametrical melodies and its metrical transformations was randomized with a web integer set generator software (http://www.random.org/integer-sets/). The same program was used to randomize the different versions or changes of timbre presented to participants. Moreover, before and after each presentation participants listened to a three minutes musical excerpt of the second experiment[2].

2.1.5. Procedure. Participants received written instructions (Appendix C) supplemented by my verbal explanations. They practiced the task at least once with Schumann’s melody Von fremden Ländern und Menschen (Of Foreign Lands and Peoples) from Kinderszenen, op.15 (Scenes from Childhood), manipulated in the same way as the rest of the auditory stimuli. They were asked to press a green button as quickly as possible each time they heard the harp timbre. Participants were instructed to press the button only once in the groups of 2 or 3 notes with harp

[2] Randomized presentations of musical excerpts of the first and second experiments can be consulted in Appendix D.

timbre. In order to obtain accurate RT they were asked to maintain their finger position, which touched the button during the entire listening to the auditory stimuli. In order to avoid distractions originating by sound wave representations of Sonic Visualiser, the screen of the computer was hidden with a black card.

The execution of the six parts of this experiment was alternated with the six parts of the experiment 2. The complete session, including the initial information and practice, took between 50 minutes and one hour.

2.2. Results

Analysis focused on participants' RTs to the changes of timbre. Participants did not make mistakes in their responses, although some of them pressed the button in each note with harp timbre. In these cases, only the responses to the first note in the groups of harp sounds have been included in this analysis. Mean RTs of each experimental condition were then calculated for each participant. Luce demonstrated that the time needed for stimulus perception and for motor responses is at least 100ms (Whelan, 2008). The result is a skewed distribution. Therefore, RTs means were logarithmically transformed in order to analyse statistically a normal distribution. These values were examined with a 2 x 2 (*Tempo* [slow/fast] x Meter [Ametrical/Metrical]) analysis of variance (ANOVA). This ANOVA revealed significant main effect of *tempo*, $F(1, 30) = 27.96$, $p = .001$, $\eta^2 = .999$, with shorter RTs for fast music than for slow music (independently of being the *stimuli* ametrical or metrical; see Table , and Figure 3). No significant effect of meter was found.

Table 2*.*

Descriptive statistics of RTs in the four conditions of Experiment 1

	Mean (SD)	Min.	Max.
SLOW *STIMULI*			
Ametrical	439 (95)	284	645
Metrical	410 (77)	313	647
FAST *STIMULI*			
Ametrical	371 (69)	283	543
Metrical	368 (79)	278	609

Note: Values of RTs mean in msec.

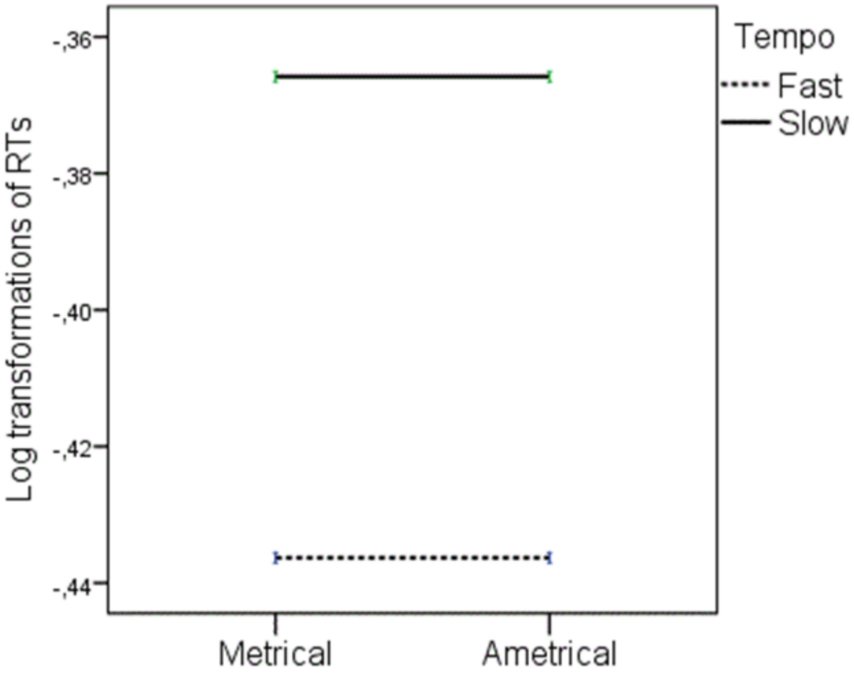


Figure 3. Graph of the relationship between the logarithmic transformations of RTs.

2.3. Discussion

The statistical analysis reveals significant differences in RTs due to *tempo*. There might be various possible explanations to these differences:

- Slow music elicits lower levels of attention, whereas fast music elicits higher levels of attention.
- Slow music provokes slower processing of auditory information and fast music the contrary.
- Slow music elicits slower motor reactions, while fast music elicits faster motor reactions.
- A combination of the previous options: slower processing of information and/or lower levels of attention may cause slower motor reactions. On the contrary, faster processing of information and/or higher levels of attention may cause faster motor actions.

Research suggests that the last option is the most probable. The connection between rhythmic perception and movement should not surprise. Music and dance have been always linked. Neuroimaging studies have shown that motor system is implicated in auditory and visual perceptual tasks of rhythm and timing (Chen, Penhune, & Zatorre, 2008; Grahn & Brett, 2007), especially when musical rhythms please listeners (Kornysheva, von Cramon, Jacobsen, & Schubotz, 2010). These interactions between the auditory and motor systems could help to develop motor therapies with music, because of rhythmic cues provides an instantaneous stability in motor control (Thaut, Kenyon, Schauer, McIntosh, 1999). The involvement of brain motor regions in rhythm perception, even when there is no motor reaction, reflects one of the building blocks of entrainment in the framework proposed by Phillips-Silver *et al*.(2010): the integration of sensory information and motor production to adjust the motor output to the rhythmic input (see first section of the literature review).

Irrespective of which of these possibilities explain what caused the differences in RTs, the results of this experiment showed that fast music elicits faster reactions than slow music. Consequently, all of these alternatives involve that participants changed their attentional and/or motor reactions and therefore they entrain with all *stimuli*. Hence, this experiment has provided evidence stating that attentional and/or motor entrainment can be achieved with ametrical music. Aperiodical music is not the only aperiodical phenomenon which entails entrainment. Numerous ecological events and speech can induce entrainment despite not showing periodicity in rhythm.

Cummins (2009) demonstrates in his experiments that entrainment is possible in speech, as long as this concept is not strictly limited to periodic processes, and instead the reciprocal influence between distinct autonomous systems is considered. He found that several physical variables are implicated in the process of coupling among speakers: fundamental frequency, amplitude envelope and excitation source (vowel versus noise). Like speech, music is a complex phenomenon which entails many elements. All of them contribute to create the meaning of music and as a result to create expectations about its continuity (Huron, 2006). For this reason, ametrical music can elicit entrainment thanks to the combination of different types of musical cues, such as melodic contour, melodic accents, motives, repetitions, etc.

An effect due to meter has not found in this experiment. This does not mean that there is no influence of metrical structure on the perception of rhythm. This experiment has been carried out with a size of sample which allows the detection of large effects, but not medium or small ones. Nevertheless, another conclusion can be extracted from these results: in the process to achieve entrainment, the contribution of all musical cues combined in ametrical rhythms is bigger than the contribution of the periodicity constructed by pulse and hierarchical meter. Therefore, the contribution of temporal periodicity is not as important as Jones hypothesize (2009). She states that: “metric patterns promote quicker binding of oscillators across embedded time levels than do rhythmic patterns. Rhythmic figures that lack consistent higher-order time spans cannot support effective entrainment of higher order oscillations; instead, loosely connected oscillations among IOI [inter-onset intervals] resolve to group segmentations” (p. 88). An equivalent parallel can be found in speech. The combination of all its elements induces entrainment in speech without the intervention of temporal periodicity. The results of this experiment show the same phenomenon: the combination of all the musical elements induces entrainment in music without the intervention of the temporal periodicity of pulse and metre. Nevertheless, these results cannot be extrapolated to all population because all the participants of this experiment were musicians. Both groups process music in different fashion (e.g.: Ohnishi, Matsuda, Asada, Aruga, Hirakata, Nishikawa,… ,Imabayashi, 2001; Schlaug, 2009), therefore different results could be found for non-musicians.

The explanation for these results could be found in the study of the phase which initiates the process of entrainment: the perception of rhythmic information, i.e., the perception of time. Huron (2006, pp. 175-202) suggests that the basis for temporal perception is predictability, and not periodicity. According to his theory, periodicity is not what allows temporal perception. Periodicity just increases predictability. This idea makes sense if it is reminded that: the capacity of predicting when something is going to happen is crucial for survival; and most ecological events do not show periodicity. Huron suggest that temporal expectations may be explained by the statistical learning of temporal schemas. Hence, pulse and metre might be periodic temporal schemas which enhance predictions. Huron bases his hypothesis on this evidence:

- The most frequent rhythms are the best processed by listeners.
- There is music in various cultures not based on a periodic pulse and metre.
- Experienced listeners can predict stereotypic timing “deviations” in performances of Western music.
- Speech rhythms are not periodic but listeners can generate expectations about them.
- Stereotypical syncopation despite not being periodic is very predictable.
- Dance rhythms can act as temporal schemas, in the same fashion that meter does.

There are three other findings, not mentioned by Huron, which also supports this hypothesis:

- Repp, London, and Keller, (2005) demonstrated that it is not necessary to have a mental subdivision in order to produce uneven rhythms.
- Musicians differentiate hierarchical metrical levels more accurately than non-musicians (Palmer & Krumhansl, 1990).
- Creutzfeldt and Ojemann (1989) found that in listening to a rhythm a small number of neurons changed their activity according to musical phrases.

If predictability, instead of periodicity, is what operates temporal perception, entrainment can be achieved with ametrical music. Various components of music may help generate expectations, as it happens in speech. Therefore, albeit pulse and metre increase predictability, they are not necessary for the creation of expectations. That is, their absence does not impede a good perception of rhythmic information, and consequently the achievement of entrainment.

More experiments with the same methodology could be done in order to add more proofs for entrainment with non-periodic music, and overcome some limitations of this experiment. The current research has been carried out with 31 participants. This number of participants only allows detecting large size effects.

Bigger samples are necessary to detect if there is a medium or small effect due to meter, as DAT predicts. This methodology could also be used to collect information about the different levels of attention which each metric position entails. Experiments with long melodies would be necessary in order to have enough responses for each metric position. The results could allow analysing the differences in the perception of metrical and ametrical melodies in more detail and therefore test the metric binding hypothesis. This methodology could also be used to test if entrainment is elicited with non-measured music. Examples of non-measured music can be found in Western music, as for example: recitative in opera (Temperley, 2012); unmeasured preludes for harpsichord composed by various French composers of the 17th century, such as Jean Phillip Rameau, and François Couperin (Moroney, 2012); and Gregorian chant performed according the theories of Solesmes school (Cardine, 2012).

Another limitation of the current experiment is due to the type of sample. All the participants were musicians. This experiment, and the other ones proposed, should be done with non-musicians as well. The analysis of the differences between RTs of these groups will provide information about the role of musical training and enculturation in entrainment. Musical *stimuli* should include Western and non-Western music in order to differentiate between the expectancies rooted in culture or in how humans process auditory information. In sum, this methodology has been useful to demonstrate that ametrical music can induce entrainment, and it has the potential for researching issues in this field which have not been tackled till now, such as entrainment with unmeasured music, or the contribution of each musical component to entrainment.

3. Experiment 2: Differences in Psychophysiological Responses and Perception of Time in Listening to Metrical and Ametrical Music

Experiment 2 was designed to obtain two types of information about the listening to metrical and ametrical music: the participant's psychophysiological responses, and their subjective experience. While participants listened to metrical/ametrical, slow/fast music excerpts, their psychophysiological responses (HR, RR, SC and temperature) were recorded (part B). After listening to each musical fragment, participants filled out a questionnaire about their perception of that music, their experience and their estimation of its duration (part A).

3.1. Part A. Differences in the perception of time in listening to metrical and ametrical music.

Firstly, according to my hypothesis based on dynamic attending theory, the estimated duration of two musical excerpts of the same duration, one metrical and the other ametrical, may be different. Ametrical music could be perceived longer if this type of music induces analytical attending, instead of future-oriented attending (for a more detailed explanation see the previous section "Attention and Estimation of Time"). The null hypothesis predicts no effects due to meter or tempo, and therefore there were no differences in the perception of the passing of time during listening to metrical/ametrical and/or fast/slow music.

Secondly, research has point out that some variables, such as familiarity with the music; pleasantness and absorption caused by music; complexity and dynamism of the music; could influence the perception of the pass of time in listening to music. According to theories which consider that time perception depends on the amount of information processed (see for a review Grondin, 2010), complex, dynamic and unfamiliar music could be perceived with a longer duration than music with the opposite characteristics. Therefore, ametrical music could be perceived longer than metrical music if participants consider that ametrical music more complex and less temporarily coherent. In addition, participants could find difficulties in the understanding of ametrical music and, consequently, they could find difficulties in getting absorbed in this type of music. The lack of pleasure and/or absorption in listening to ametrical music could involve that participants perceive this kind of music more lasting than metrical music. The null hypothesis predicts no correlations between the estimated duration of musical excerpts and the other independent variables studied: familiarity, pleasantness, and absorption, complexity, and dynamism.

3.2. Part B. Differences in psychophysiological responses in listening to metrical and ametrical music.

An omnibus null hypothesis predicts effects of neither psychophysiological measure (HR, RR, SC, and temperature) due to meter and *tempo*. It also predicts no synchronization between HR and music pulse, and RR and duration of the bars in listening to metrical music. A linear interpretation of the entrainment model predicts that in metrical music:

- An effect on HR due to tempo: HR increases with fast tempi, and decreases with slow tempi. In addition, HR gets closer to music pulse progressively.
- An effect on respiration due to *tempo*: RR increases with fast *tempi*, and decreases with slow *tempi*. In addition, RR gets closer to bar periods progressively.
- I hypothesized that fast tempi could increase body temperature, and slow tempi decrease it, due to a change on subjective time perception (see the previous section dedicated to entrainment and psychophysiological responses to music).
- Changes in SC reveal emotional activity. Both metrical excerpts could be equally moving for musicians familiar to their style. I hypothesized that there will not be differences on SC due to tempo.

Hypotheses for the psychophysiological responses to ametrical music are based on the next idea: music without a clear pulse has not got the purpose of inducing movement, but a passive response. Therefore, the results predicted by this hypothesis are:

- A progressive diminution of HR.
- A progressive diminution of RR.
- A progressive diminution of temperature which could be caused by a slowing down in the perception of time. This slowing down could be induced by ametrical music if this type of music entails analytical attending.

- Like in listening to metrical music, I hypothesized that there will not be differences on SC due to tempo and meter (metrical or ametrical) because both musical excerpts could be equally moving for musicians.

3.3. Method

3.3.1. Participants. Experiment 2 was carried out with the same participants as Experiment 1.

3.3.2. Stimuli and conditions. I selected four piano pieces for the four conditions of the experiment: two Beethoven's pieces for the metrical conditions and two Messiaen's pieces for the ametrical one (Table 2; scores in Appendix E). I extracted excerpts of them with Audacity software in order to create auditory stimuli with the same duration: three minutes. Bernardi, Porta, and Sleight (2006) did not find a significant difference between the effects induced by two or four minutes musical tracks. Considering that Messiaen's music might be not familiar to participants, and ametrical music may need more time to induce entrainment than the metrical music used by Bernardi and his colleagues, I experimented with longer musical fragments. Two seconds fade-in and fade-out was added in the beginning and end of the audio files with Audacity for avoiding disconcerting commencements and terminations. As Messiaen replaced the concept of pulse by a short value which multiplies freely (Messiaen, 1944, p.14), the same short value was used as reference in the performances of ametrical and metrical music. The only piece which had changes of tempi was *L'Aloutte Calandrelle*. Most of the excerpt extracted in this piece was performed following the composer indication ♪ = 132. Some short passages alternated were indicated to be performed as ♪ = 108 and ♪ = 160. The mean of these *tempi* indications is ♪ = 134, almost the same as the main metronomic indication.

Iwanaga (1995) found that people prefer music with *tempi* closer to their HR. The HR of adults within normal daily situations ranges from 70 to 100 cycles per minute. The *tempi* of the musical excerpts selected for this experiment are out of this range. This could allow recognizing the genuine effect of music on HR from the similarity between a normal HR and a similar musical pulse.

In the fast excerpts the more abundant values were demisemiquavers and semiquavers, and in the slow ones quavers and semiquavers. Another feature in common between Messiaen's and Beethoven's chosen pieces were the complexity of the musical phrases. None of them had a regular and simple organization, and therefore it was not easy to predict their structure and continuity. In Beethoven's excerpts bars were not strongly marked, and consequently not recognizable in a clear and easy fashion.

Table 2

Musical excerpts used as stimuli in Experiment 2 for each condition.

	SLOW	FAST
TEMPI	*♪ = 52*	*♪ = 132*
AMETRICAL: Olivier Messiaen	(1928-1929). Préludes pour piano: 4. Instants défunts (Dead instants). *Bars: 19 – 46. Recording: 1'41" - 4'41".*	(1956-1958). Catalogue d´oiseaux. Livre 5: VIII. L'Alouette calandrelle. (Bird Catalogue: Book: Short-toed Lark). *Bars: 27- 79. Recording: 1' 45"– 4' 45"*.
METRICAL: Ludwig van Beethoven	*(1801).* Piano Sonata no.13 in E flat major, op. 27 no.1 III. *Adagio con espressione – attacca. Bars: 1- 25. Recording: 0" – 3'.*	*(1800).* Piano Sonata no.11 in B flat major, op. 22. IV. *Rondo. Allegretto. Bars: 32 – 129. Recording: 55" – 3'55".*

Note: The scores of these musical pieces can be consulted in Appendix F.

3.3.3. Equipment. Participants listened to the musical excerpts played by a Mac computer with circumaural headphones. Psychophysiological data were gathered using proComp5 Infiniti™ hardware, Biograph software form Thought Technologies™, and a Windows computer. I collected blood volume pulse data (BVP) in order to obtain heart rate (HR), RR (RR), temperature (T), and SC or galvanic skin response (SC). Surface electrodes sewn in Velcro™ straps were used to record BVP (around middle finger on left hand in right handed participants, and on the contrary on left handed participants), SC (around index and ring fingers in the same hand as BVP sensors), and RR (around abdomen). Temperature sensor was place on palms of the hand with adhesive straps. Data about perception of time and other features which could be related were gathered using questionnaires on paper (see Appendix E).

3.3.4. Design. The design was a two-way repeated measures factorial. Dependent variables were meter (levels metrical and non-metrical) and tempo (levels slow and fast). The independent variables in phase A were BVP, RR, T, and SC. The independent variable in part A was estimated duration of each musical excerpt (from zero seconds to five minutes).

In part A I also carried out a correlational research. I gathered data in scales from 1 to 7 about the levels of:

- Familiarity with the music.
- Pleasantness caused by the music.
- Absorption with the music.
- Complexity of the music.
- Dynamism of the music.

The purpose was to investigate if there is any correlation between any of these dependent variables and the estimated duration of each musical excerpt (independent variable), and therefore the influence that metrical/ametrical and slow/fast music might have in the subjective perception of time.

Order of presentations of the four auditory stimuli was counterbalanced with eight combinations of them. These combinations were ordered and this order was repeated in order to have the same number of participants who have listened to stimuli in the same order. Between the listening to each musical excerpt a session of the first experiment was carried out in order to limit the influence caused by the previous piece on psychophysiological responses elicited by the next one.

3.3.5. Procedure. Participants received written instructions (Appendix C) supplemented by my explanations. After the signature of the informed consent, they were fitted with the temperature sensor in order to have enough time to arrive to a stable measure before starting to record baseline data. After the practice of the first experiment, participants were fitted with the rest of the sensors. Two three minutes baseline silent periods were recorded: one before the block of metrical musical excerpts, and another one before the block of the ametrical ones. Unfortunately, data of baseline periods had not been recorded due to technical problems with Infiniti software. I instructed participants to be relaxed and still (especially their hands with the sensors) during the recording of psychophysiological data during the baseline periods and the music listening time. Participants listened to the metrical fragments once, and the ametrical ones twice, in order to obtain more data about these conditions (ametrical fast/slow music). I instructed them to relax and to concentrate freely on the music, without thinking in the posterior questions or other issues. After listening to each stimulus, participants filled in the questionnaire (Appendix E) about their experience and perception of the music. I encouraged them be honest in their answers, because there were not correct or wrong answers.

3.4. Results of part A: Differences in the perception of time in listening to metrical and ametrical music

Two types of data were gathered in this part of the experiment: the representation in centimetres of the durations of the musical excerpts estimated by participants translated to seconds; and the scoring for familiarity, complexity, absorption and pleasantness provided by each participant in each experimental condition.

I carried out three 2 x 2 repeated-measures ANOVA with the first type of data (summary of the mean and SD in Table 4):

- Tempo [slow, fast] x Meter [metrical, ametrical] with the data duration estimated by participants after listening to the metrical music, and the first presentation of the ametrical music.
- Tempo [slow, fast] x Meter [metrical, ametrical] with the data duration estimated by participants after listening to the metrical music, and the second presentation of the ametrical music.
- Tempo [slow, fast] x Presentation [first presentation, second presentation] with the data duration estimated by participants after the first and the second presentations of the ametrical music.

None of these ANOVA revealed any significant effect.

I analysed the second type of data with eight multiple regressions with the method of force entry in SPSS, because this is an exploratory analysis due to the lack of previous research which could help to hypothesize predictions. Estimated duration of musical excerpts was the independent variable, whereas familiarity, pleasantness, absorption, dynamism and complexity were the dependent variables. The summary of these analyses is exposed in Tables 4, 5 and 6. No significant correlation has been found between the duration of the musical excerpts estimated by the participants in the experiment and any of the other variables (familiarity, pleasantness, absorption, complexity and dynamism).

Table 4

Mean and SD of the duration of the four musical excerpts estimated by participants in each exposition to them (values in seconds). The duration of all of them was 180 seconds.

	FAST		SLOW	
	1st exposition	2nd exposition	1st exposition	2nd exposition
METRICAL	189.40 (31.44)		183.90 (48.52)	
AMETRICAL	186.75 (45.41)	177.92 (45.32)	175.75 (43.82)	152.68 (33.70)

Table 5

Summary of Eight Multiple Regressions Analyses for Variables Predicting Duration Estimated of Metrical and Ametrical Music (N = 37)

	Mean (SD)	*B*	*SE B*	*β*	*p*
1. Metrical fast music					
Estimated time	189.40* (31.44)				
Familiarity	5.16 (1.80)	1.69	3.50	.097	.632
Pleasantness	5.62 (1.30)	-6.11	5.87	-.256	.306
Absorption	5.30 (1.18)	-2.81	5.57	-.101	.618
Complexity	4,92 (1,32)	7.09	4.12	.298	.095
Dynamism	5,54 (0.96)	5.75	6.21	.176	.361
R^2 = .177, $F(5,36)$ = 1.33, p = .276					
2.Metrical slow music					
Estimated time	183.90 (48.52)				
Familiarity	5.35 (1.70)	-6.17	5.63	-.22	.282
Pleasantness	6.00 (1.27)	-4.80	10.62	-.13	.654
Absorption	5.43 (1.30)	11.89	11.04	.31	.290
Complexity	4.14 (1.21)	-26	7.68	-.01	.973
Dynamism	3.98 (1.40)	-.36	6.67	-.01	.957
R^2 = .060, $F(5,36)$ = .388, p = .85					
3.Ametrical fast music, mean of both presentations					
Estimated time	182.34 (41,84)				
Familiarity	4.20 (1,59)	-4.14	6.10	-.158	.503
Pleasantness	4.45 (1,46)	-3.69	8.29	-.130	.659
Absorption	4.88 (1,23)	1.09	8.94	.032	.904
Complexity	5.12 (1,24)	12.13	8.52	.361	.165
Dynamism	5.07 (1,20)	-11.31	8.03	-.325	.169
R^2 = .166, $F(5,36)$ = 1.235, p = .317					
4.Ametrical slow music, mean of both presentations					
Estimated time	179.49 (38.51)				
Familiarity	4.20 (1.60)	-5.27	4.27	-.219	.226
Pleasantness	5.28 (1.13)	4.96	9.57	.146	.608
Absorption	5.12 (1.09)	5.08	8.96	.144	.574
Complexity	3.91 (1.27)	13.65	6.70	.452	.050
Dynamism	3.47 (1.19)	-2.98	6.55	-.093	.652
R^2 = .177, $F(5,36)$ = 1.338, p = .275					

	Mean (SD)	*B*	*SE B*	*β*	*p*
5.Ametrical fast music, first presentation					
Estimated time	186.75 (45.41)				
Familiarity	3.65 (1.89)	-2.26	5.79	-.094	.699
Pleasantness	4.19 (1.69)	-0.68	8.99	-.026	.940
Absorption	4.65 (1.38)	-5.79	10.20	-.176	.575
Complexity	5.22 (1.33)	6.62	9.23	.195	.479
Dynamism	5.27 (1.37)	-1.01	8.37	-.030	.905
R^2 = .102, F(5,36) = .706, p = .623					
6.Ametrical fast music, second presentation					
Estimated time	177.92 (45.32)				
Familiarity	4.76 (1.74)	-2.48	5.48	-.095	.654
Pleasantness	4.70 (1.56)	-8.28	6.87	-.285	.237
Absorption	5.11 (1.41)	9.72	7.78	.302	.221
Complexity	5.03 (1.36)	10.70	7.15	.322	.145
Dynamism	4.86 (1.44)	-12.95	6.59	-.411	.059
R^2 = .177, F(5,36) = 1.330, p = .278					
7. Ametrical slow music, first presentation					
Estimated time	175.75 (43.82)				
Familiarity	3.81(1.61)	-3.94	5.54	-.145	.482
Pleasantness	5.14 (1.34)	-0.08	8.49	-.003	.992
Absorption	5.08 (1.26)	12.94	834	.371	.131
Complexity	3.86 (1.56)	7.32	5.91	.262	.224
Dynamism	3.38 (1.53)	2.16	5.54	.076	.700
R^2 = .161, F(5,36) = 1.187 , p = .338					
8. Ametrical slow music, second presentation					
Estimated time	152.68 (33.70)				
Familiarity	4.70 (1.78)	-4.91	4.69	-.259	.304
Pleasantness	5.43 (1.21)	7.15	8.65	.258	.415
Absorption	5.16 (1.30)	-1.96	6.16	-.076	.753
Complexity	3.95 (1.33)	10.16	5.18	.402	.059
Dynamism	3.57 (1.17)	-4.20	5.78	-.146	.473
R^2 = .152, F(5,36) = 1.108 , p = .376					

Note: The minimum *F* critical value for assessing the goodness of these models, considering their degrees of freedom, is approximately 2.5. No significant *p* (p < .005) has been found. *Values of estimated time in seconds.

Table 6

Summary of the Significant Correlations between the Variables Predicting Duration Estimated of Metrical and Ametrical Music (N = 37)

			r	*p*
METRICAL				
Slow		Familiarity * Absorption (1)	.419	.005
Fast		Familiarity * Pleasantness (2)	1.000	.001
		Pleasantness * Absorption (3)	1.000	.001
AMETRICAL				
Slow	Mean	Pleasantness * Absorption (3)	.742	.001
		Pleasantness * Complexity (4)	-.481	.001
		Complexity *Dynamism (5)	.559	.001
	Presentation 1	Familiarity * Absorption (1)	.460	.002
		Familiarity * Pleasantness (2)	.540	.001
		Pleasantness * Absorption (3)	.705	.002
		Pleasantness * Complexity (4)	-.455	.002
		Complexity *Dynamism (5)	.484	.001
	Presentation 2	Familiarity * Absorption (1)	.454	.002
		Familiarity * Pleasantness (2)	.730	.001
		Pleasantness * Absorption (3)	.692	.001
		Complexity *Dynamism (5)	.520	.001
Fast	Mean	Familiarity * Absorption (1)	.570	.001
		Familiarity * Pleasantness (2)	.690	.001
		Pleasantness * Absorption (3)	.710	.001
		Complexity *Dynamism (5)	.695	.001
	Presentation 1	Familiarity * Absorption (1)	.517	.001
		Familiarity * Pleasantness (2)	.689	.001
		Pleasantness * Absorption (3)	.742	.001
		Complexity *Dynamism (5)	.727	.001
	Presentation 2	Familiarity * Absorption (1)	.600	.001
		Familiarity * Pleasantness (2)	.536	.001
		Complexity *Dynamism (5)	.611	.001

In sum:

- Neither meter (metrical/ametrical), nor *tempo* (slow/fast), nor repetition (first/second presentation of the music) elicit any significant effect ($p < .005$) in the estimation of the duration of the musical excerpts.
- None of the independent variables (familiarity, pleasantness, absorption, complexity and dynamism) makes a significant contribution ($p < .005$) to predicting the duration of the musical excerpts estimated by the participants in this experiment.

3.5. Discussion of part A: Differences in the perception of time in listening to metrical and ametrical music

The purpose of the experiment was to determine if there were differences in the perception of time in listening to metrical and ametrical music. For this reason, I chose musical excerpts which could have similar characteristics for listeners. I looked for music with similar levels of complexity and dynamism. I selected ametrical music which could be familiar to musicians and caused pleasure and concentration in listening to. The ratings for familiarity, pleasantness, absorption, complexity and dynamism (see Table 5) show that this aim was quite well accomplish. All of them were quite familiar for participants (the biggest difference of means are 1.5 in a scale of 7), pleasant (the biggest difference of means is 1.3). They got similar levels of absorption (the biggest difference of means is 1.4). They perceived fast music more dynamic and complex than slow music, independently if music was metrical or ametrical. The similar characteristics of musical excerpts with the same tempo give more reliability to the results of the experiment, because there were no differences in the aforementioned factors and therefore the four conditions of the experiment were comparable. ANOVAs have not revealed any significant effect due to meter (ametrical/metrical) or tempo (slow/fast) in the perception of duration of music. Consequently, the hypothesis based on the dynamic attending theory has not been demonstrated: ametrical music excerpts were not perceived longer than fragments of metrical music of the same duration. According to Jones et al. (1993), ametrical music has got a low temporal coherence. This type of music could induce in listeners an analytical attention, and consequently, a different perception of time. This experiment has not found any significant difference in the perception of time duration in listening to metrical or ametrical music. Like I pointed out in the discussion of the first experiment, ametrical music can exhibit temporal coherence thanks to the combination of all the musical elements. Therefore, listeners could shift between different structural levels although they do not have the temporal periodicity of the hierarchical metrical structure.

In the previous experiment has been demonstrated that attentional entrainment is possible with ametrical music. Participants may perceive its temporal coherence thanks to the contribution of all musical elements. Therefore, listeners could shift between different temporal structural levels although these structures were not periodic. Consequently, listeners could use both analytic attending as future-oriented attending. This could imply that there were no differences in the estimation of the duration of ametrical and metrical music.

The duration of all the musical excerpts was 180 seconds. The means of the estimated duration according to participants were very close to their real duration. It seems that participants were quite accurate in measuring the pass of time at this scale. Nevertheless, there are reasons for doubting about their accuracy. Participants could use the duration of the silent periods for recording baseline data as reference. They knew that these periods lasted three minutes. They were informed about the duration of these periods in order to maintain them calm thanks to knowing what was going to happen. On the other hand, the standard deviations of these means reveal great differences between participants (approximately from half minute to one minute). Most of the participants commented that this task was difficult for them. Some of them remarked that they were very bad in measuring the pass of time. Their statements may explain the great variation between participants' data. A possible explanation of these differences is that in general people are quite good in measuring short time intervals, albeit there are individuals who do not perform well this type of task. Clarke and Krumhansl, (1990) speculated about the development of a sense of time due to musical training, which could explain the accuracy in absolute duration perception which numerous participants showed. Nonetheless, one of the participants with a very high level of musical mastery declared that she was very bad in estimating the duration of musical excerpts.

The multiple regressions analysis did not reveal any significant contribution in the estimation of the duration of musical fragments of any of the variables studied: familiarity and absorption with music; pleasantness caused by music; and complexity and dynamism of music. These results could contradict the theories about the perception of time which are based on the idea of the dependency of perceived duration and the amount of information processed (Clarke & Krumhansl, 1990; Grondin, 2001, 2010);Ornstein, 1969). Non-familiar, or complex, or dynamic music may involve the processing of more amounts of information and therefore be perceived with longer duration than music with the opposite characteristics. Absorption could also involve the processing of more information in each instant.

Nevertheless, no contribution of absorption in the estimation of the duration of music has been found. On the other hand, although it is a popular believe that pleasant events last less than normal or disgusting ones, literature about the influence of emotions in the perception of time is limited and very recent (Grondin, 2010). Experiments with intervals of time shorter than five seconds in contemplating faces with different expressions seem to corroborate this belief. It has been hypothesised that arousal caused by emotions could accelerate the mechanism for judging time (in a review of Droit-Vole & Gil, 2009, cited by Grondin, 2010). Nonetheless, this experiment has not found any significant contribution of a positive emotion, like pleasure, in judging of the duration of the musical excerpts.

The relationships, revealed by statistical analysis, between familiarity and pleasantness; familiarity and absorption; pleasantness and absorption; and the inverse relation between pleasantness and complexity; are not any surprise. Hargreaves (1984) found that familiarity with music and liking are related. The relationships between familiarity, pleasantness and absorption may support the theory about aesthetic pleasure created by Reber, Schwarz, and Winkielman (2004).They propose that the fluency in processing an object condition the aesthetic response: the more fluent process entails the more positive response. Their proposition could be tinged from the point of view of the concept of flow. In order to get absorption into music it should be a balance between the complexity of the music and the ability to process it (Csikszentmihalyi, 1990). From this perspective, listeners may not get absorbed by music if its processing is too easy for them.

Statistical analyses reveal a relationship between complexity and dynamism only in ametrical music. This relation could be interpreted as a relation between motion and music. The more musical events to process could entail the perception of more musical activity, and therefore the more dynamism. Nevertheless, this explanation can be discussed because of this significant relation has not appeared with metrical music. This fact could be due to the influence of familiarity in the perception of complexity. The metrical music used in the experiments was more familiar to participants than ametrical music. Therefore, they could perceive metrical music as less complex than ametrical music. This could explain why participants do not relate complexity and dynamism in metrical music.

The manipulation of time perception is a common topic in musical aesthetics since various centuries ago. Stravinsky called music the art of time, and Susanne Langer the virtual time, in opposition to the actual time of clocks (Reimer & Jeffrey, 1992). However, as Clarke and Krumhansl (1990) highlighted, research on perception of time in performing or listening to music is limited. More experiments with the methodology employed in this experiment could be done to go into this topic in more depth. Bigger samples, composed by musicians and non-musicians, should be used to overcome the limitations of this experiment. In addition, music with different characteristics which could involve a different perception of time could be used in order to improve the understanding of time perception, such as: music with contrasting emotions; familiar, unfamiliar or known music; very complex versus very simple music; music from different musical cultures; relaxing music versus music which could induce movement, such as dance music. These experiments may also work with diverse time scales (from few seconds, to few minutes, and almost an hour).

3.6. Results of part B: Differences in psychophysiological responses in listening to metrical and ametrical music

I analysed the data collected from various perspectives. Firstly, I compared the means of heart and RRs, SC and temperature obtained for the entire duration of each condition. Secondly, I compared the responses during the first 30 seconds with the responses during the last 30 seconds to each musical excerpt. The purpose of this analysis was studying the possible existence of a gradual process of entrainment with metrical and ametrical music.

In order to study the psychophysiological responses according to the first perspective, I carried out a total of fifteen 2 x 2 repeated-measures ANOVAs analysing the means of the responses during the three minutes that each musical excerpt lasted. These means corresponded to HRs, RRs, SC levels, number of peaks in SC lines (inflexion points equal or greater than 0.2 microsiemens) and temperatures. I completed ten ANOVAs (Meter [Metrical/Ametrical] x Tempo [Fast/Slow]): five ANOVAs in order to compare the responses in listening to metrical excerpts and the first exposition to the ametrical excerpts; and five ANOVAs in order to compare the responses in listening to metrical excerpts and the second exposition to the ametrical excerpts. I calculated five ANOVAs (Exposition [First/Second] x Tempo [Fast/Slow]) in order to compare the responses in listening the first and second expositions to ametrical excerpts. Only one significant effect was found in all of these analyses. A significant main effect due to exposition was found in the ANOVA which analysed the SC levels of the listening to the first and second presentations of the ametrical music, $F(1, 35) = 22.243$, $p = .001$, $\eta^2 = .996$. The levels of SC were greater in the second presentation of the ametrical excerpts (see Figure 4.

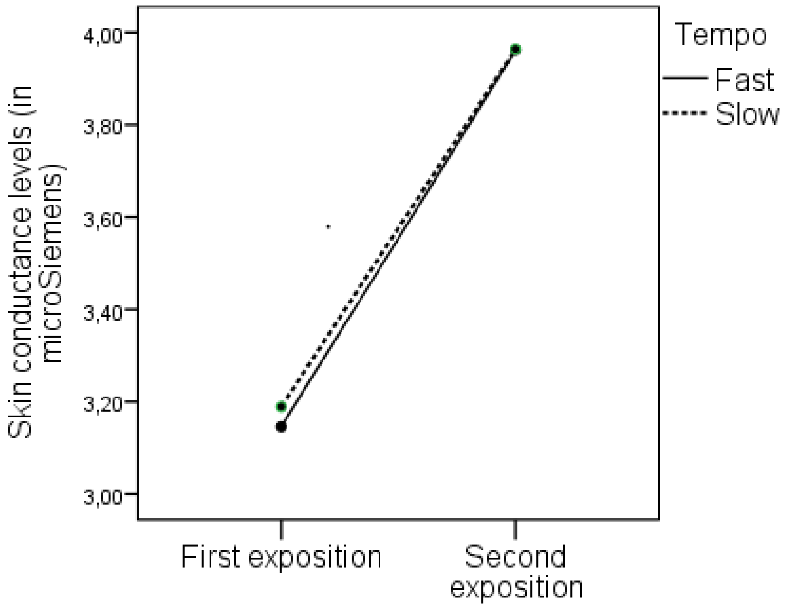


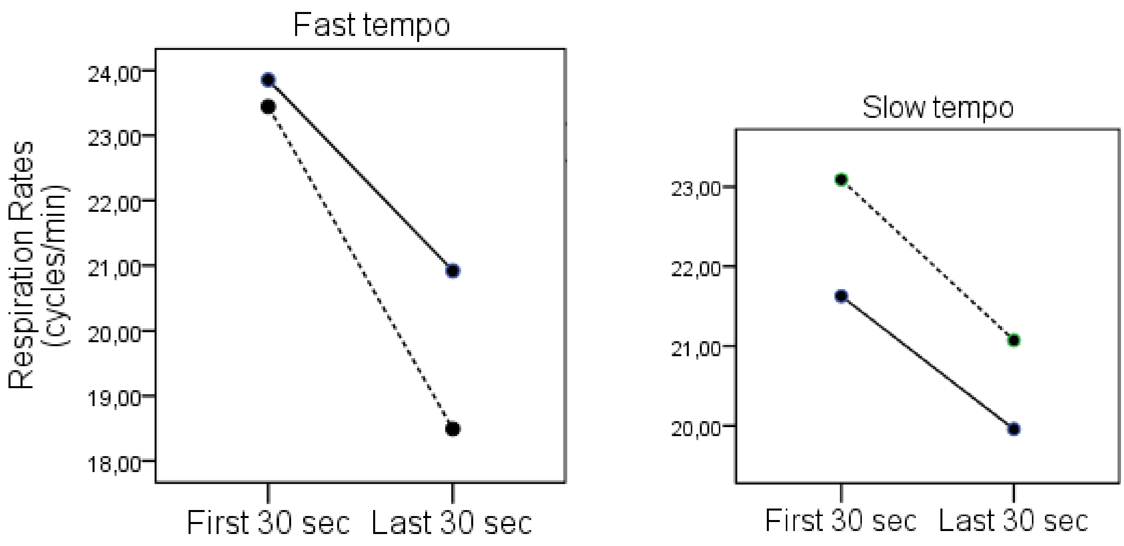
Figure 4. Skin conductance levels in listening to ametrical music.

In order to study the changes in psychophysiological responses according to the second perspective, I carried out a total of twelve 2 x 2 x 2 repeated-measures ANOVAS analysing the means of the responses during the first and last 30 seconds of each musical excerpt. These means corresponded to HRs, RRs, SC levels, and temperatures. I completed eight ANOVAs (Meter [Metrical/Ametrical] x Tempo [Fast/Slow] x Process [Beginning/Ending]): four ANOVAs in order to compare the responses in listening to metrical excerpts and the first exposition to the ametrical excerpts; and four ANOVAs in order to compare the responses in listening to metrical excerpts and the second exposition to the ametrical excerpts. I calculated four ANOVAs (Exposition [First/Second] x Tempo [Fast/Slow] x Process [Beginning/Ending]) in order to compare the responses in listening the first and second expositions to ametrical excerpts. No significant effect was found in HR and temperature responses. Main effects due to process were found in the three aforementioned ANOVAs which analysed RRs in listening to:

Metrical stimuli and the first presentation of the ametrical ones:

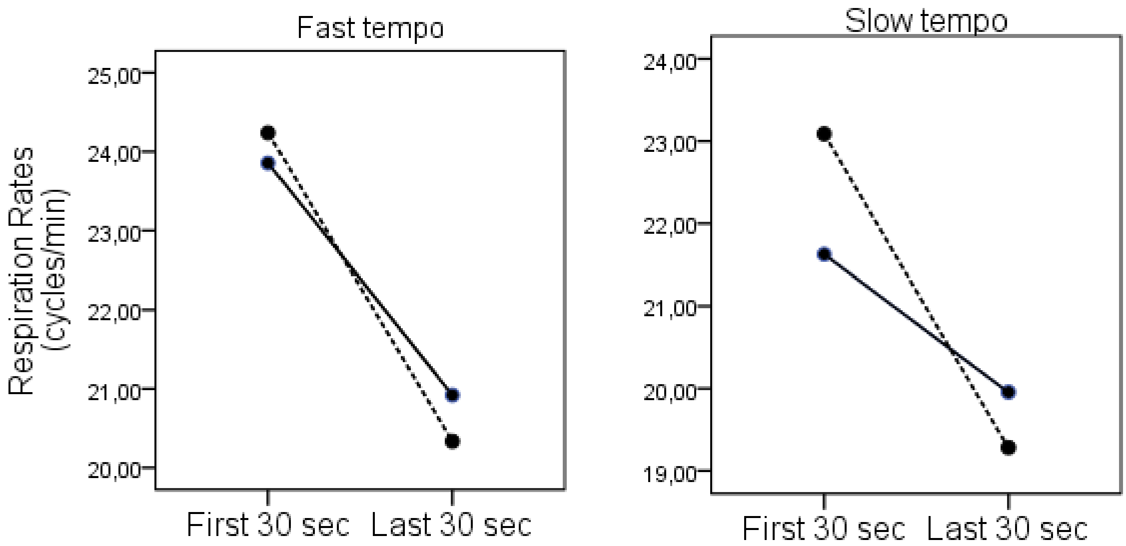
- $F(1,35) = 11.583$, $p = .002$, $\eta^2 = .911$.
- Metrical stimuli and the second exposition to the ametrical ones:
- $F(1,35) = 14.848$, $p = .001$, η2 = .963.
- The first and second presentation of ametrical stimuli:
- $F(1,35) = 23.430$, $p = .001$, η2 = .997.

In the three cases the statistical analyses revealed that RRs were slower during the last 30 seconds than during the first 30 seconds in listening to each stimulus (see Figures 5, 6, and 7).



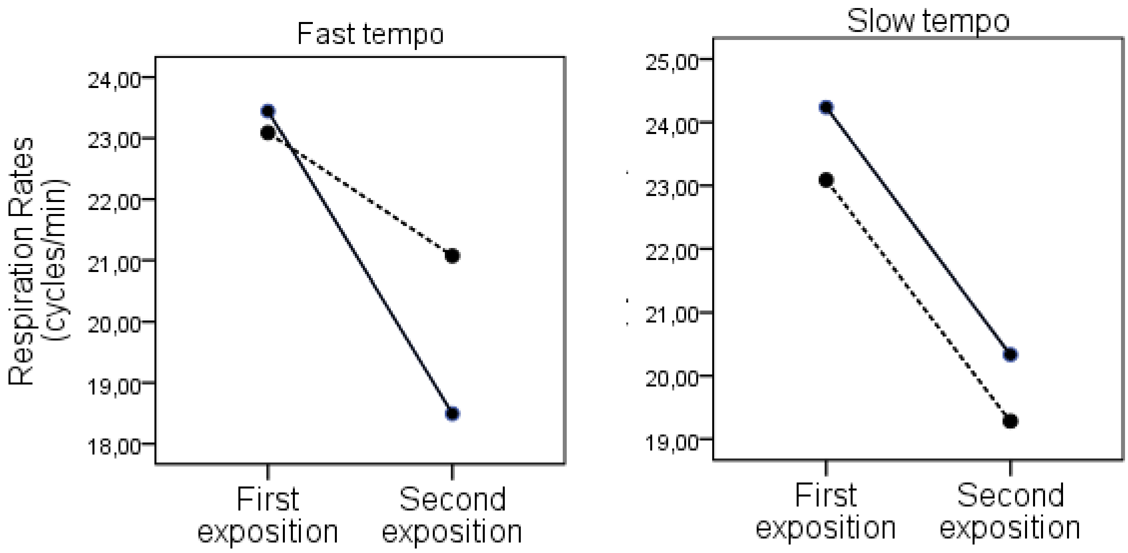
Note: —— Metrical music, ----- Ametrical music

Figure 5. Evolution of RR in listening to metrical *stimuli* and the first exposition of ametrical *stimuli.*



Note: —— Metrical music, ----- Ametrical music

Figure 6. Evolution of RR in listening to metrical *stimuli* and the second exposition of ametrical *stimuli.*



Note: —— First 30 seconds of each *stimuli*

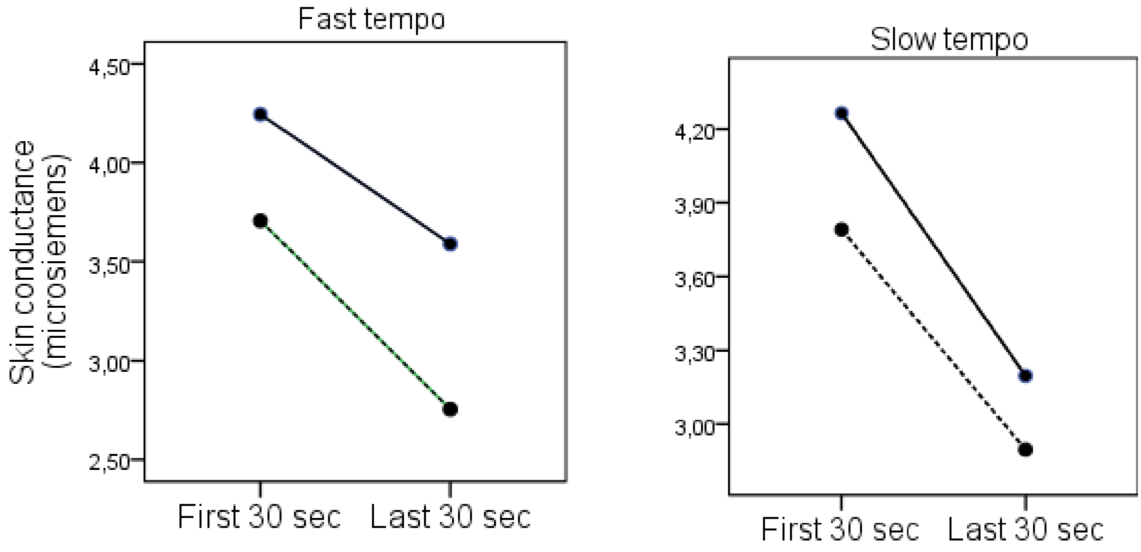
----- Last 30 seconds of each *stimuli*

Figure 7. Evolution of RR in listening to the first and second expositions of ametrical *stimuli.*

Main effects due to process were found in the three aforementioned ANOVAs which analysed SC levels in listening to:

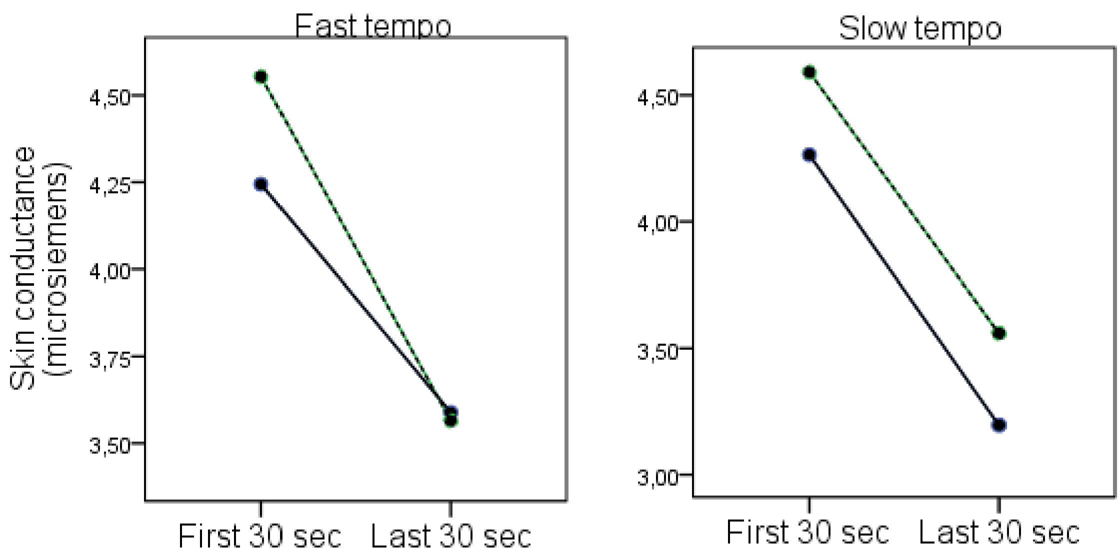
- Metrical stimuli and the first presentation of the ametrical ones:
- $F(1,35) = 26.432$, $p = .001$, $\eta 2 = .999$.
- Metrical stimuli and the second exposition to the ametrical ones:
- $F(1,35) = 27.175$, $p = .001$, $\eta 2 = .999$.
- The first and second presentation of ametrical stimuli:
- $F(1,35) = 41.238$, $p = .001$, $\eta 2 = 1.000$.

In the three cases the statistical analyses revealed that SC levels were lower during the last 30 seconds than during the first 30 seconds in listening to each stimulus (see Figures 8 and 9). In addition, in this last ANOVA which analysed the two expositions to ametrical excerpts, a main effect due to exposition was found, $F(1,35) = 22.174$, $p = .001$, $\eta 2 = .996$. The SC levels were higher in the second exposition than in the first exposition to ametrical musical fragments (see Figure 10).



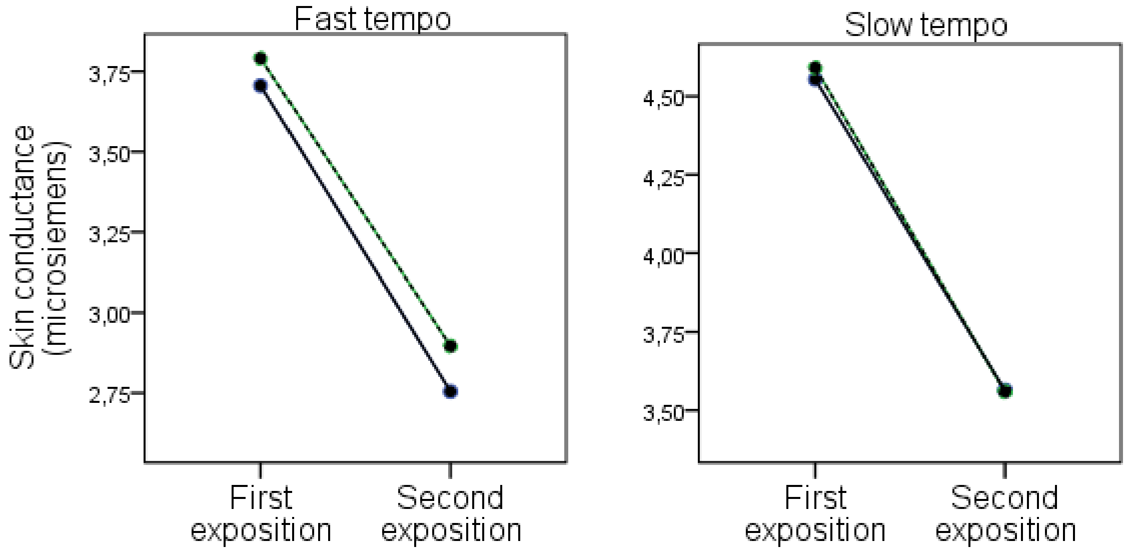
Note: —— Metrical music, ----- Ametrical music

Figure 8. Evolution of SC in listening to metrical *stimuli* and the first exposition of ametrical *stimuli.*



Note: —— Metrical music, ----- Ametrical music

Figure 9. Evolution of SC in listening to metrical *stimuli* and the second exposition of ametrical *stimuli.*



Note: —— First 30 seconds of each *stimuli*

----- Last 30 seconds of each *stimuli*

Figure 10. Evolution of RR in listening to the first and second expositions of ametrical *stimuli.*

I approached psychophysiological responses from a third perspective. I tested if HRs and RRs could synchronize with respectively pulse and bars in listening to metrical music. Results are displayed in Table 7. No mathematical ratio has been found between these music and biological rates.

Table 3

Comparison of Pulse and Bar Rates of Metrical Stimuli with Participants' HR and RR during Listening to Metrical Stimuli.

	Metrical structure of musical stimuli		Psychophysiological responses	
	Pulse	Bars per minute (Type of bar)	Heart rate Mean (SD)	Respiration rate Mean (SD)
Slow	26	8.66 (3/4)	70.62 (9.01)	20.66 (5.17)
Fast	66	33 (2/4)	72.45 (9.62)	21.98 (5.53)

3.7. Discussion of part B: Differences in psychophysiological responses in listening to metrical and ametrical music

The hypotheses about metrical music based on a linear interpretation of entrainment model predicted faster HRs and RRs in listening to fast music than in listening to slow music. Nevertheless, the results of this experiment do not confirm these hypotheses. No effect due to *tempo* has been found in none of the psychophysiological responses during listening to metrical excerpts: neither in the analyses of the means corresponding to listening to entire stimuli, nor in the analysis of the changes arose during the process of listening to musical excerpts. In addition, HRs and RRs did not approach progressively to pulse and bar rates (as the linear interpretation of entrainment model predicted). On the contrary, RRs decreased in listening to the slow metrical excerpts, and also the fast ones.

Most of the investigations distinguish between responses elicited by stimulative or excitative music and those elicited by sedative or relaxing music. Research on effects of music on HR and RR has obtained contradictory results (Hodges, 2010). Some researchers found that any music increased HR and RR. Others have found that stimulative music tends to increase HR, whereas sedative music produces the opposite effect in HR and RR (for a list see Hodges, 2010). Etzel *et al.* (2006) and Bernardi *et al.* (2006) suggest that *tempo* could be the responsible of the effects of music on HR and RR, instead of emotional experiences elicited by music. The results of this experiment seem to be another piece in a difficult puzzle to solve.

The Beethoven's musical excerpts used as *stimuli* in this experiment are neither excitative nor sedative. The *Adagio con espressione* is emotionally very intense, thanks to great changes of dynamic (from *pianissimo* to *forte*), chromatic passages, syncopations between the melody and the accompaniment (bars 9-16), and the insistent repetition of notes and chords in the melody and the accompaniment. It has a slow *tempo*, but it cannot be described as sedative. The *Rondo Allegretto* is a piece with a great variety of moods, from calm (e.g. bars 53-57, 112-121), to furious (e.g. bars 67-80). It is clearly metrical, but at the same time it is rhythmically quite complex. On example of this complexity is the *fugato* passage (bars 90-95), with the syncopated dialogue between both hands composed with only one short rhythmic motive. Perhaps this music could be classified in the group of the excitative music, although some of its passages are calm. Nevertheless, participants' RRs and SC levels decreased when they listened to it. And the same happened when they listened to the *Adagio*, and Messiaen's ametrical music. These psychophysiological responses indicate that they became relaxed with all the musical *stimuli* of the experiment (Boiten, Frijda, & Wientjes, 1994).

Bernardi *et al.* (2006) experimented with different musical styles. They found that faster *tempi* elicited significant increases in respiration and hear rate, independently of the musical style. They used a fragment of Vivaldi's *Presto* from "Estate", Concerto for Violin, Orchestra, and Continuo no. 2, Op. 8 as example of classical fast music. The accompaniment in this piece marks the pulse persistently during all its duration. It is a music which induces physical movement to listeners. Beethoven's tracks used in the current experiment do not produce the same reaction. They are rhythmically more complex and more intellectual. Participants relaxed in listening to them. Their attitude was passive. This is the reaction that I predicted for ametrical conditions.

Messiaen, in his piece *L'alouette calandrelle,* turns listeners in strollers in a forest where birds and cicada are protagonists. Therefore, listeners adopt an attitude of observation to the sounds of nature. Messiaen's prelude *Instants défunts* was strongly influenced by Debussy's music (Griffiths, 2012), and consequently by musical impressionism. Impressionists, influenced by physiopsychology, were interested in reflecting in their art the impressions or sensations because they believed that they were the embryos of the knowledge of world and self (Passler, 2012). Therefore, impressionist music induces listeners to adopt an attitude of observation. This relaxed attitude has been observed in the respiration and SC participants' responses to Messiaen's musical excerpts.

I selected musical *stimuli* which could evoke the same type of sensations, in spite of their stylistic differences, in order to focus on the differences of the metric structure. The ratings of familiarity, complexity, pleasantness, dynamism and absorption were very similar for ametrical and metrical excerpts. In addition, the effects of metrical and ametrical *stimuli* on respiration and SC have been the same.

All of them induced relaxation in participants, which could be interpreted as a passive attitude of observation. The similarity in the responses of metrical and ametrical excerpts could also explain why no differences in the perception of time between them have been found.

My hypothesis predicted a decrease of HR and RR in listening to ametrical music. Results of this experiment confirm a decrease of RR, but not a decrease in HR. Research has demonstrated the influence of respiration on heart (a review in Brown, Beightol, Koh, & Eckberg, 1993). Experiments with longer musical *stimuli* are necessary to test if effects on HR took more time to appear than effects on RR. On the other hand, although the decrease of SC levels was not predicted, this decrease reinforces the data which indicates that the ametrical *stimuli* induced relaxation in participants. These results confirm the hypothesis that entrainment with ametrical music is possible if entrainment is defined from a non-linear perspective. This hypothesis predicted that ametrical music which involves a passive attitude induces in body a state of rest. The results of this experiment suggest that some metrical music can also induce this passive attitude and its corresponding psychophysiological responses.

The results revealed a significant effect of repetition on SC levels. In the second exposition of the ametrical *stimuli* to the participants, SC was higher than in the first presentation of the same *stimuli*. At the same time, the ratings of pleasantness and absorption for the second presentation were higher than for the first presentation. This fact confirms previous research results which linked familiarity and liking in listening to music, such as experiments conducted by (Hargreaves, 1984).

No effect has been found in temperature data of the experiment. Therefore, the hypothesis which suggested that body temperature and *tempo* could be linked has not been demonstrated. More experiments should be carried out in order to overcome the limitations of the current research. Musical *stimuli* should be longer and have more simple and clear rhythms.

4. General Discussion

Results of the first experiment demonstrate that attentional entrainment with ametrical music is possible. Therefore, the obstacle which impeded inserting the research of musical entrainment in the general investigation of entrainment has been got through. This first cognitive entrainment is necessary for achieving entrainment in other physiological responses. The investigation of entrainment in this last level is more difficult. Research of effects of music on psychophysiological responses shows contradictory results. A frequent assumption in this domain is the classification of music in two main types: exciting or stimulative music, and sedative or relaxing music (Hodges, 2010). Nevertheless, there is music which cannot be classified in this way, as it has been demonstrated in the previous section of this paper. In addition, this classification does not help in finding good predictions for guiding research. The incongruence of results from different investigations is one proof of the inadequacy of this classification. In order to advance in the research of this domain, other perspectives should be considered.

In my opinion, entrainment could provide a useful framework in the research of effects of music in psychophysiological responses. The capacity to detect and adapt to rhythms of the environment provides evolutionary advantages. Therefore, the human mechanisms which allow entrainment have been evolved with survival purposes. Once rhythmic information from environment is detected, individuals can react in the most adequate way to each situation. The reaction or adaption can be only a change in RR and HR, to move in a particular way, or to communicate with others. In some circumstances, the best reaction may be remaining still, observing and listening to environment in order to inform future reactions. In other circumstances, the best reaction may be moving, whereas in other situations the communication with other individuals may be very advantageous. Albeit the diversity of experiences provided by music is enormous, the effects of music could be researched starting from these three basic reactions to rhythmic signals: contemplation, movement, communication.

- Contemplation. In the previous section, the musical analysis of the musical excerpts used as *stimuli* have shown that they provided a common basic experience: an attitude of "contemplation" or "observation" of music. All of them elicited in participants a progressive relaxation, observed in the decrease of RR and SC levels.

- Movement. The musical tracks with fast *tempo* used by Bernardi *et al.* (2006) elicited significant increases in HR and RR, independently of their musical style. They have in common a marked pulse which induced movement. The best examples of music which induce to move coordinately are any kind of music for dance and work songs.
- Communication. The participants' responses to the *stimuli* used by Bernardi *et al*. (2009) in their research could be located in this third type of reactions. Bernardi and his colleagues found that crescendos or musical emphasis provided skin vasoconstriction, and increases in blood pressure, and HR. Reactions to musical emphases could be interpreted as reactions similar to prosodic emphases in verbal communication. Juslin and Laukka (2003) suggested that vocal expression and music performance use similar acoustic cues to communicate discrete emotions. A possible common origin of these cues could be the existence of standard, and quite universal, rules to encode discrete emotions into patterns of muscle actions (Scherer, 1986). In order to perform this encoding, one of the three abilities which allows the capacity for entrainment is necessary: the integration of sensory information and motor production to adjust the motor output to the rhythmic input (see in the first section of the literature review).

Some musical works could elicit responses corresponding to more than one of these typologies, especially western classical pieces. The history of classical music has been build up mixing elements from vocal music (religious and secular), dance music, and idiomatic music created for sophisticated instruments and instrumental ensembles. Experiments with musical excerpts which represent clearly each type of reactions to music could help to test if this framework is useful.

Bharucha, Curtis, and Paroo (2006) investigated the conscious experiences elicited by music. A parallelism can be found between their proposal and these three types of reactions to music explained by the entrainment framework. They proposed three main examples of conscious experiences elicited by music: the perception of the musical structure, affect or emotion, and the sense of motion. They can be related with the reactions to music explained in my proposal: the perception of the musical structure can be interpreted in a more general sense as the contemplation of music; the expression of emotion can be inserted in the broader concept of communication; and the sense of motion are clearly equivalent in both proposals.

Another parallelism can be found in three important therapeutic uses of music: in sensorimotor rehabilitation (Thaut (2005); improving communication by the expression of feelings and the enhance of interpersonal relationships; and inducing relax, for example in clinical contexts (Bunt, 2012). These three types of reactions or experiences could guide future research. This framework could help in the understanding of the effects of music in human body and mind, and improving the therapeutic uses of music.

5. Conclusions

The framework for entrainment proposed by (Phillips-Silver et al., 2010) suggested a common origin for all entrainment phenomena researched by biological and social sciences. Entrainment explained the adaptive advantages achieved in being able to detect rhythmic information in environment and react to it. Nonetheless, the research of musical entrainment could not be inserted in this common framework because it was focused on the temporal periodicity of pulse as the origin of musical entrainment, while most ecological events, and verbal and gestural communication do not normally show this periodicity. The experiments of the current research provide evidence that entrainment with ametrical music is possible.

Firstly, it has been demonstrated that musicians can achieve attentional entrainment with ametrical music. The first experiment shows that the combination of all musical elements induces entrainment without the intervention of the temporal periodicity of pulse and metre. Nevertheless, it has not provided information about the contribution of pulse, metre and other musical elements to entrainment. Further experimental research (also with non-musicians) is necessary in order to understand how ametrical music can induce entrainment. Predictability seems a good candidate for substituting temporal periodicity as mechanism to initiate the process of entrainment. In addition to evidence used by Huron in order to support this hypothesis, other evidence has been added (see Discussion of the first experiment, pp. 30-31). This research has provided a methodology which could be useful to the investigations necessary for superseding the limitations of the current study.

Secondly, the second experiment provided evidence of entrainment with ametrical music. RR and SC decrease during listening to slow and fast, metrical and ametrical music, indicating a process of relaxation. The equal results for all the musical *stimuli*, and the similarity between the experiences elicited by all of them, leaded to apply the hypothesis formulated for the listening of ametrical music to the metrical excerpts used in the experiment. This was possible because of the similarities between the experiences elicited by all of them. A comparison between the results of the current and previous research, and between the musical analyses of the musical *stimuli* used both in current and previous research, allows proposing a new framework to explain the effects of music on psychophysiological responses based on entrainment phenomenon. I suggested that there could be three types of reactions to music: contemplation, movement and communication. These three types of experiences could reflect the three types of reactions elicited after the processing of rhythmic signals in ecological contexts: remaining still observing, moving, and trying to communicate to other individuals. Contemplation could be elicited by various types of music, such as impressionist music, plain chant, and contrapuntal music, among others. Movement could be elicited fundamentally by any style of dance music or music inspired in it. The experience of communication could be elicited by music which its main objective is communicating emotions to listeners. The influence of prosodic cues of speech could be very important in this type of music. Some examples could be opera arias, popular songs, and instrumental music whose melodies are similar to those of vocal music. Further research should be done to test this theory. What can be learned from the second experiment is the importance of the selection of musical *stimuli*, of their musical analysis, and of collecting data about the subjective experience of participants. In addition, listening to music is a dynamic process, and therefore, the analysis of the psychophysiological data should take into account the evolution in participants' responses. This research could contribute to the understanding of the effects of music in human body and mind, and therefore it could enhance the therapeutic uses of music.

The current research has not found any significant difference in the perception of time in listening to metrical or ametrical music. All musical *stimuli* employed lasted three minutes, therefore, the perception of time in other scales (seconds or larger periods) have not been tested. In addition, results could be influenced by the similarity of the type of experience elicited by these musical excerpts. The differences in how musicians and non-musicians perceive time in listening to ametrical and metrical music have not been researched. The knowledge about the perception of time in music (either in performing or listening to it) is very limited. Its investigation involves many difficulties due to the complexity of this issue and the multiple variables that it implies. The perception of time in music has been a common topic in the reflexions of composers, performers and philosophers, especially in the 20th century. Important personalities such as Stravinsky, Hindemith or Susan Langer believed that music is the art of time (Riemer & Wright, 1992). Music could be a useful domain where the perception of time could be researched. The framework of entrainment proposed by Phillips-Silver et al.(2010) could be helpful in guiding this research, because in this model the perception of rhythmic signals involves evolutionary advantages in ecological contexts.

In sum, the research about musical entrainment could not be inserted in the general research about entrainment because it assumed that the origin of this phenomenon was the temporal periodicity of pulse or beat. Nevertheless, the current research offers evidence to the existence of entrainment with music without the temporal periodicity provided by pulse. Consequently, the superseding of this limitation locates the research of musical entrainment in a privileged position. Music is the perfect archetype of entrainment with numerous dimensions to investigate related to behaviour, communication (from the most intellectual to the most primitive; from the perspective of cognitive psychology to the study of gestural communication; with or without the connection to language and speech), and movement. In addition, diverse types of population can be investigated depending on their characteristics: musicians and non-musicians (differentiated by types of musical learning experiences), and people from different cultures (differentiated by their type of musical enculturation processes). Moreover, the research of musical entrainment might have theoretical and practical implications. Entrainment could help to understand the role of music in human beings' evolution. On the other hand, it could help to understand the usefulness and benefits of music, and in consequence the uses of music to enhance therapeutic applications and daily life.

References

Barnes, R., & Jones, M. R. (2000). Expectancy, attention, and time. *Cognitive psychology*, *41*(3), 254–311. doi:10.1006/cogp.2000.0738

Beethoven, L. van (1800). *Piano Sonata no. 11 in B flat major, op. 22, IV. Rondo. Allegretto*. [Recorded by D. Barenboim]. On *BEETHOVEN. The Piano Sonatas. DANIEL BARENBOIM*. [CD]. Hamburg: Polydor International GmbH. (1984).

Beethoven, L. van (1800). *Piano Sonata no. 11 in B flat major, op. 22, IV. Rondo. Allegretto*. In *Klaviersonaten, Band I. Urtext.* München: G. Henle Verlag (1952/1980), pp. 208-215.

Beethoven, L. van (1801). *Piano Sonata no. 13 in E flat major, op. 27 no. 1, III. Adagio con espressione*. [Recorded by D. Barenboim]. On *BEETHOVEN. The Piano Sonatas. DANIEL BARENBOIM.* [CD]. Hamburg: Polydor International GmbH. (1984).

Beethoven, L. van (1801). *Piano Sonata no. 13 in E flat major, op. 27 no. 1, III. Adagio con espressione*. In *Klaviersonaten, Band I. Urtext.* München: G. Henle Verlag (1952/1980), pp.239-240.

Bernardi, L, Porta, C., & Sleight, P. (2006). Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. *Heart (British Cardiac Society)*, *92*(4), 445–52. doi:10.1136/hrt.2005.064600

Bernardi, L., Porta, C., Casucci, G., Balsamo, R., Bernardi, N. F., Fogari, R., & Sleight, P. (2009). Dynamic interactions between musical, cardiovascular, and cerebral rhythms in humans. *Circulation*, *119*(25), 3171–3180. Retrieved from http://circ.ahajournals.org/cgi/doi/10.1161/CIRCULATIONAHA.108.806174

Bharucha, J. J., Curtis, M., & Paroo, K. (2006). Varieties of musical experience. *Cognition*, *100*(1), 131–72. doi:10.1016/j.cognition.2005.11.008

Boiten, F. A. , Frijda, N. H., & Wientjes, C. J. (1994). Emotions and respiratory patterns: review and critical analysis. *International Journal of Psychophysicology*, *17*(2), 103–28. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7995774

Bradt, J. (2010). The Effects of Music Entrainment on Postoperative Pain Perception in Pediatric Patients. *Music and Medicine*, *2*(3), 150. Retrieved from http://mmd.sagepub.com/content/2/3/150.short

Brown, S. W., & Boltz, M. G. (2002). Attentional processes in time perception: Effects of mental workload and event structure. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(3), 600–615. doi:10.1037//0096-1523.28.3.600

Brown, T. E., Beightol, L. A., Koh, J., & Eckberg, D. L. (1993). Important influence of respiration on human R-R interval power spectra is largely ignored Important influence of respiration power spectra is largely ignored on human R-R interval. *Journal of Applied Physiology*, *75*, 2310–2317.

Bunt, L. (2012). Music therapy. *In Grove Music Online*. *Oxford Music Online.* Retrieved from http://www.oxfordmusiconline.com/subscriber/article/grove/music/19453.

Cardine, E. (2012) Solesmes. In *Grove Music Online. Oxford Music Online*. Retrieved from http://www.oxfordmusiconline.com/subscriber/article/grove/music/26139

Chan, M. F., Chung, Y. F. L., Chung, S. W. A., & Lee, O. K. A. (2009). Investigating the physiological responses of patients listening to music in the intensive care unit. *Journal of clinical nursing*, *18*(9), 1250–7. doi:10.1111/j.1365-2702.2008.02491.x

Chen, J. L., Penhune, V. B., & Zatorre, R. J. (2008). Listening to musical rhythms recruits motor regions of the brain. *Cerebral cortex, 18*(12), 2844–54. doi:10.1093/cercor/bhn042

Clarke, E.F. (2004). Timers, oscillators and entrainment: A commentary on Clayton, Sager and Will (2004). In time with the music: The concept of entrainment and its significance for ethnomusicology. *ESEM CounterPoint*, 1¸ 49-50.

Clarke, E. F. (1987). Levels of structure in the organization of musical time. *Contemporary music review*, *2*(1), 211–238. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/07494468708567059

Clarke, E. F.., Krumhansl, C. L. (1990). Perceiving musical time. *Music Perception*, *7*(3), 213–252. Retrieved from http://www.jstor.org/stable/10.2307/40285462

Clayton, M., Sager, R., & Will, U. (2005). In time with the music: The concept of entrainment and its significance for ethnomusicology. *European meetings in Ethnomusicology*, *11*, 3–142. Retrieved from http://oro.open.ac.uk/2661/

Creutzfeldt, O., & Ojemann, G. (1989). Neuronal activity in the human lateral temporal lobe. III. Activity changes during music. *Experimental Brain Research*, *77*, 490–498.

Collier, J. & Burch, M. (2000). Symmetry, Levels and Entrainment. *Proceedings of the International Society for Systems Sciences,* 1-23.

Collier, J., Burch, M. (1998). Order from rhythmic entrainment and the origin of levels through dissipation. *Symmetry Culture Science. 9,* 165-178.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. New York: Harper and Row.

Cummins, F. (2009). Rhythm as an affordance for the entrainment of movement. *Phonetica*, *66*(1-2), 15–28. doi:10.1159/000208928

Dainow, E. (1977). Physical Effects and Motor Responses to Music. *Journal of Research in Music Education*, *25*(3), 211–221.

Drake, C., Jones, M. R., & Baruch, C. (2000). The development of rhythmic attending in auditory sequences: attunement, referent period, focal attending. *Cognition*, *77*(3), 251–88. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11018511

Ellis, R. J., Koenig, J., & Thayer, J. F. (2012). Getting to the Heart: Autonomic Nervous System Function in the Context of Evidence-Based Music Therapy. *Music and Medicine*, *4*(2), 90–99. doi:10.1177/1943862112437766

Etzel, J. a, Johnsen, E. L., Dickerson, J., Tranel, D., & Adolphs, R. (2006). Cardiovascular and respiratory responses during musical mood induction. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *61*(1), 57–69. doi:10.1016/j.ijpsycho.2005.10.025

Grahn, J. a, & Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. *Journal of cognitive neuroscience*, *19*(5), 893–906. doi:10.1162/jocn.2007.19.5.893

Griffiths, P. (2012) Messiaen, Olivier. In *Grove Music Online. Oxford Music Online*. Retrieved, from http://www.oxfordmusiconline.com/subscriber/article/grove/music/18497

Grondin, S. (2001). From Physical Time to the First and Second Moments of Psychological Time, *127*(1), 22–44.

Grondin, S. (2010). Timing and time perception: a review of recent behavioral and neuroscience findings and theoretical directions. *Attention, Perception, & Psychophysics*, *72*(3), 561–582. doi:10.3758/APP

Haas, F., Distenfeld, S., & Axen, K. (1986). Effects of perceived musical rhythm on respiratory pattern. *Journal of Applied Physiology*, *61*(3), 1185–1191. Retrieved from http://www.sciencedirect.com/science/article/B6WVB-45CF5WY-239/2/d9e854c9c7a99fa446879ec4dd7f3cfc

Hargreaves, D. J. (1984). The Effects of Repetition on Liking for Music. *Journal of Research in Music Education*, *32*(1), 35–47.

Hodges, D. A. (2010). Psychophysiological measures. In Juslin, P. N., Sloboda, J. A. (Eds.), *Handbook of Music and Emotion. Theory, Research, Applications* (pp. 279-311). Oxford: Oxford University Press.

Hodges, D.A (2009). Bodily responses to music. In Hallam, S., Cross, I., Thaut, M., *The Oxford Handbook of Music Psychology* (pp.121-130). Oxford: Oxford University Press.

Huron, D. (2006). *Sweet Anticipation. Music and the Psychology of Expectation*. Cambridge, Massachusetts, MIT Press.

Iwanaga, M. (1995). Relationship between heart rate and preference for tempo of music. *Perceptual and motor skills*, *81*(2), 435–40. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8570336

Jones, M. R. (1976). Time, Our Lost Dimension: Toward a New Theory of Perception, Attention, and Memory. *Psychological Review*, *83*(5), 323–355.

Jones, M.R. (1987). Dynamic pattern structure in music: recent theory and research. *Perception & psychophysics*, *41*(6), 621–34. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3615156

Jones, M. R. (1992). Attending to Musical Events. In M. R. Jones & S. Holleran (Eds.), *Cognitive bases of musical communication* (pp. 91-110). Washington: American Psychological Association.

Jones, M.R. (2004). Attention and Timing. In J. Neuhogg (Ed.), *Ecological Psychoacoustics* (pp. 49-85). San Diego: Elsevier Academic Press.

Jones, M.R. (2009). Musical time. In S. Hallam, I. Cross, & M. Thaut (Eds.), *The Oxford Handbook of Music Psychology* (pp. 81-92). Oxford: Oxford University Press.

Jones, M. R., & Boltz, M. (1989). Dynamic attending and responses to time. *Psychological review*, *96*(3), 459–91. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2756068

Jones, M. R., Moynihan, H., MacKenzie, N., & Puente, J. (2002). Temporal Aspects of Stimulus-Driven Attending in Dynamic Arrays. *Psychological Science*, *13*(4), 313–319. doi:10.1111/1467-9280.00458

Jones, M.R., & McAuley, J. . D. (2005). Time judgments in global temporal contexts. *Perception & psychophysics*, *67*(3), 398–417. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16119390

Jones, M.R., & Yee, W. (1997). Sensitivity to time change: The role of context and skill. *Journal of Experimental Psychology: Human Perception and Performance*, *23*(3), 693. Retrieved from http://psycnet.apa.org/journals/xhp/23/3/693/

Jones, M.R. (1981). Only Time Can Tell : On the Topology of Mental Space and Time. *Critical Inquiry*, *3*, 557–576.

Jones, Mari Riess, Johnston, H. M., & Puente, J. (2006). Effects of auditory pattern structure on anticipatory and reactive attending. *Cognitive psychology*, *53*(1), 59–96. doi:10.1016/j.cogpsych.2006.01.003

Juslin, P. N., & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: different channels, same code? *Psychological Bulletin*, *129*(5), 770–814. doi:10.1037/0033-2909.129.5.770

Khalfa, S., Roy, M., Rainville, P., Dalla Bella, S., & Peretz, I. (2008). Role of tempo entrainment in psychophysiological differentiation of happy and sad music? *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *68*(1), 17–26. doi:10.1016/j.ijpsycho.2007.12.001

Koelsch, S., Schröger, E., & Tervaniemi, M. (1999). Superior pre-attentive auditory processing in musicians. *Neuroreport*, *10*(6), 1309–13. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10363945

Kornysheva, K., von Cramon, D. Y., Jacobsen, T., & Schubotz, R. I. (2010). Tuning-in to the beat: Aesthetic appreciation of musical rhythms correlates with a premotor activity boost. *Human brain mapping*, *31*(1), 48–64. doi:10.1002/hbm.20844

Kouwenhoven, F. (2004). Some remarks on music as reorganized time: A commentary on Clayton, Sager and Will (2004). In time with the music: The concept of entrainment and its significance for ethnomusicology. ESEM *CounterPoint, 1*¸ 52-55.

Large, E. W., & Jones, M. R. (2000). On synchronizing movements to music The dynamics of attending: How people track time-varying events. *Human Movement Science*, *19*(4), 527–566.

Large, E. W., & Kolen, J. F. (1994). Resonance and the Perception of Musical Meter. *Connection Science*, *6*(2-3), 177 – 208.

Large, E., Jones, M. R. (1999). The dynamics of attending: How people track time-varying events. *Psychological review*, *106*(1), 119–159. Retrieved from http://psycnet.apa.org/psycinfo/1999-10188-005

Lee, O. K. A., Chung, Y. F. L., Chan, M. F., & Chan, W. M. (2005). Music and its effect on the physiological responses and anxiety levels of patients receiving mechanical ventilation: a pilot study. *Journal of clinical nursing*, *14*(5), 609–20. doi:10.1111/j.1365-2702.2004.01103.x

London, J. (2012). Rhythm. In *Grove Music Online. Oxford Music Online*. Retrieved, from http://www.oxfordmusiconline.com/subscriber/article/grove/music/45963pg3

Madison, G. (2006). Experiencing groove induced by music: Consistency and phenomenology. *Music perception*, *24*(2), 201–208. Retrieved from http://www.jstor.org/stable/10.1525/mp.2006.24.2.201

Madison, Guy, Gouyon, F., Ullén, F., & Hörnström, K. (2011). Modeling the tendency for music to induce movement in humans: First correlations with low-level audio descriptors across music genres. *Journal of Experimental Psychology: Human Perception and Performance*,*37*(5), 15-78. doi:10.1037/a0024323

Mates, J., Müller, U., Radil, T., & Pöppel, E. (1994). Temporal integration in sensorimotor synchronization. *Journal of Cognitive Neuroscience*, *6*(4), 332–340. Retrieved from http://www.mitpressjournals.org/doi/abs/10.1162/jocn.1994.6.4.332

Merker, B. H., Madison, G. S., & Eckerdal, P. (2009). On the role and origin of isochrony in human rhythmic entrainment. *Cortex*, *45*(1), 4–17. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19046745

Messiaen, O. (1928-1929). *Préludes pour piano: 4. Instants défunts*. [Recorded by P. Hill]. On *Visions de l'amen; Préludes, etc.*[CD]. Bristol: Regis. (Dec. 1992).

Messiaen, O. (1928-1929). *Préludes pour piano: 4. Instants défunts*. Paris : Durand, 1930.

Messiaen, O. (1942). *Quatuor pour la fin du temps*. Paris: Durand.

Messiaen, O. (1956). *The technique of my musical language*. (J. Satterfield, Trans.). Paris: Alphonse Leduc Éditions Musicales. (Original work published 1944).

Messiaen, O. (1956-1958). *Catalogue d'oiseaux. Livre 5 : VIII. L'Alouette Calandrelle*. [Recorded by P. Hill]. On *Catalogue d'oiseaux. Books 4-6*. [CD]. Rosslyn Hill: Regis. (Apr. 5-7, 1988).

Messiaen, O. (1956-1958). *Catalogue d'oiseaux. Livre 5 : VIII. L'Alouette Calandrelle*. Paris : Leduc, 1964.

McAuley, J. D., Jones, M. R., Holub, S., Johnston, H. ., & Miller, N. S. (2006). The time of our lives: life span development of timing and event tracking. *Journal of experimental psychology. General*, *135*(3), 348–67. doi:10.1037/0096-3445.135.3.348

Merker, B. H., Madison, G. S., & Eckerdal, P. (2009). On the role and origin of isochrony in human rhythmic entrainment. *Cortex*, *45*(1), 4–17. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19046745

Moelants, D. (2006). Perception and performance of aksak metres. *Musicae Scientiae*, *X*, 147–172.

Möckel, M., Röcker, L., Störk, Vollert, J., Danne, O., Eichstädt, H., Müller, R., Hochrein, H. (1994). Inmediate physiological responses of healthy volunteers to different types of music: cardiovascular, hormonal and mental changes. *European*

Journal of Applied Physiology, *68*, 451–459. Retrieved from http://www.springerlink.com.eresources.shef.ac.uk/content/p6440w1v6w548360/fulltext.pdf

Moroney, D. (2012) Prélude non mesuré. In *Grove Music Online. Oxford Music Online*. Retrieved from http://www.oxfordmusiconline.com/subscriber/article/grove/music/22290

Nozaradan, S., Peretz, I., Missal, M., & Mouraux, A. (2011). Tagging the neuronal entrainment to beat and meter. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *31*(28), 10234–40. doi:10.1523/JNEUROSCI.0411-11.2011

Ohnishi, T., Matsuda, H., Asada, T., Aruga, M., Hirakata, M., Nishikawa, M., Katoh, a, et al. (2001). Functional anatomy of musical perception in musicians. *Cerebral cortex (New York, N.Y. : 1991)*, *11*(8), 754–60. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11459765

Ornstein, R. E. (1969). *On the experience of time*. Harmondsworth: Penguin.

Palmer, C., & Krumhansl, C. L. (1990). Mental representations for musical meter. *Journal of experimental psychology. Human perception and performance*, *16*(4), 728–41. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2148588

Pantev, C., Roberts, L. E., Schulz, M., Engelien, a, & Ross, B. (2001). Timbre-specific enhancement of auditory cortical representations in musicians. *Neuroreport*, *12*(1), 169–74. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11201080

Pashler, H. (2001). Perception and production of brief durations: Beat-based versus interval-based timing. *Journal of Experimental Psychology: Human Perception and Performance*, *27*(2), 485–493. Retrieved from http://psycnet.apa.org/journals/xhp/27/2/485/

Pasler, J. "Impressionism." In *Grove Music Online. Oxford Music Online*. Retrieved from: http://www.oxfordmusiconline.com/subscriber/article/grove/music/50026.

Phillips-Silver, A. J., Aktipis, C. A., & Bryant, G. A. (2010). The Ecology of Entrainment: Foundations of Coordinated Rhythmic Movement. *Music Perceptiion: An Interdisciplinary Journal*, *28*(1), 3–14.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience? *Personality and social psychology review : an official journal of the Society for Personality and Social Psychology, Inc*, *8*(4), 364–82. doi:10.1207/s15327957pspr0804_3

Repp, B. H., London, J., & Keller, P. E. (2005). Production and synchronization of uneven rhythms at fast tempi. *Music Perception*, *23*(1), 61–78. Retrieved from http://www.jstor.org/stable/10.1525/mp.2005.23.1.61

Rickard, N. S. (2004). Intense emotional responses to music: a test of the physiological arousal hypothesis. *Psychology of Music, 32*(4), 371–388. doi:10.1177/0305735604046096

Rider, M. S. (1985). Entrainment Mechanisms Are Involved in Pain Reduction, Muscle- Relaxation, and Music-Mediated Imagery. *Journal of Music Therapy*, *22*(4), 183–192.

Rider, M. S., Floyd, J. W., & Kirkpatrick, J. (1985). The Effect of Music, Imagery, and Relaxation on Adrenal Corticosteroids and the Re-Entrainment of Circadian-Rhythms. *Journal of Music Therapy*, *22*(1), 46–58. Retrieved from http://www.sciencedirect.com/science/article/B6WVB-45CD86T-1M1/2/49a31a5fb68bb26e482422ed4b247213

Riemer, B., & Wright, J. E. (1992). Time. In Riemer, B., & Wright, J. E. (Eds.), *On the nature of Musical Experience*. Niwot: University Press of Colorado.

Scherer, K. R. (1986). Vocal affect expression: a review and a model for future research. *Psychological bulletin*, *99*(2), 143–65. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3515381

Schlaug, G. (2009). Music, musicians, and brain plasticity. In Hallam, S., Cross, I., Thaut, M., *The Oxford Handbook of Music Psychology* (pp.197-207). Oxford: Oxford University Press.

Seddon, F., & Biasutti, M. (2009). A comparison of modes of communication between members of a string quartet and a jazz sextet. *Psychology of Music*, *37*(4), 395–415. doi:10.1177/0305735608100375

Sloboda, J., Lamont, A., Greasley, A. (2009). Choosing to hear music. Motivation, process, and effect. In Hallam, S., Cross, I., Thaut, M., *The Oxford Handbook of Music Psychology* (pp.431-440). Oxford: Oxford University Press.

Stevens, C., Byron, T. (2009). Universals in music processing. In Hallam, S., Cross, I., Thaut, M., *The Oxford Handbook of Music Psychology* (pp.14-23). Oxford: Oxford University Press.

Strait, D. L., Kraus, N., Skoe, E., & Ashley, R. (2009). Musical experience and neural efficiency: effects of training on subcortical processing of vocal expressions of emotion. *The European journal of neuroscience*, *29*(3), 661–8. doi:10.1111/j.1460-9568.2009.06617.x

Su, Y.H., & Pöppel, E. (2012). Body movement enhances the extraction of temporal structures in auditory sequences. *Psychological Research*. 76(3), 373-382. doi:10.1007/s00426-011-0346-3

Temperley, N. (2012) Recitative. In *Grove Music Online. Oxford Music Online*. Retrieved from http://www.oxfordmusiconline.com/subscriber/article/opr/t114/e5531

Thaut, M., & McIntosh. (2010). How Music Helps to Heal the Injured Brain: Therapeutic Use Crescendos Thanks to Advances in Brain Science By Michael H. Thaut, Ph. D., and Gerald C. *Cerebrum*. Retrieved from http://www.dana.org/assets/0/16/32/492/bd99578eae69440c89b1bd7217550cb5.pdf

Thaut, M. H. (2005). *Rhythm, Music, and the Brain. Scientific Foundations and Clinical Applications*. *lavoisierfr*. New York and London: Routledge.

Thaut, M. H., Kenyon, G.P., Schauer, M.L., McIntosh, G. C. (1999). The Connection Between Rhythmicity and Brain Function. Implications for Therapy of Movement Disorders. *Engineering In Medicine And Biology*, 101–108.

Thompson, W., & Graham, P. (2005). Seeing music performance: Visual influences on perception and experience. *Semiotica*, *156*, 203–227. Retrieved from http://digitalcommons.ryerson.ca/cgi/viewcontent.cgi?article=1008&context=psych

Todd, N. P. M., Cousins, R., & Lee, C. S. (2007). The Contribution of Anthropometric Factors to Individual Differences in the Perception of Rhythm, *2*(1), 1–13.

Trainor, L. J. (McMaster U. (2007). Do Preferred Beat Rate and Entrainment to the Beat Have a Common Origin in Movement? *Empirical Musicology Review*, *2*(1), 18–20. Retrieved from http://dana.org/WorkArea/showcontent.aspx?id=28846

Trainor, L. J., Gao, X., Lei, J., Lehtovaara, K., & Harris, L. R. (2009). The primal role of the vestibular system in determining musical rhythm. *Cortex; a journal devoted to the study of the nervous system and behavior*, *45*(1), 35–43. doi:10.1016/j.cortex.2007.10.014

Wearden, J H, Penton-Voak, I. S. (1995). Feeling the heat: Body temperature and the rate of subjective time, revisited. *The Quarterly Journal Of Experimental Psychology. Section B: Comparative and Physiological Psychology*, *48*(2), 37–41. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/14640749508401443

Whelan, R. (2008). Effective analysis of reaction time data. *The Psychological Record*, *58*, 475–482. Retrieved from http://opensiuc.lib.siu.edu/tpr/vol58/iss3/9/

Yamamoto, T., & Miyake, Y. (2000). Analysis of interaction in musical communication and its modeling. *SMC 2000 Conference Proceedings. 2000 IEEE International Conference on Systems, Man and Cybernetics. "Cybernetics Evolving to Systems, Humans, Organizations, and their Complex Interactions" (Cat. No.00CH37166)*, *2*, 763–768. doi:10.1109/ICSMC.2000.885941

Yee, W., Holleran, S., & Jones, M. R. (1994). Sensitivity to event timing in regular and irregular sequences: influences of musical skill. *Perception & psychophysics*, *56*(4), 461–71. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7984401

Zentner, M., & Eerola, T. (2010). Rhythmic engagement with music in infancy. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(13), 5768–73. doi:10.1073/pnas.1000121107

Appendix A

Musical Background Questionnaire

DIFFERENCES IN THE PERCEPTION OF 19TH AND 20TH CENTURIES MUSIC

BACKGROUND INFORMATION FORM **Participant number ________**

Age	
Gender	
Handedness	
Main Musical Instrument	
Years of performing	
Years of music lessons	
Number of hours listening to music per week	
Number of hours playing per week	

Main styles of performance:

Preferred musical styles to listen:

Do you like modern classical music? Indicate with a number how much do you like it (from 1, I hate it; to 7, I love it).You can add any commentary.

Appendix B

Changes of Timbre in the Musical*Stimuli* of the Experiment 1

Note: Notes with harp timbre are marked with a horizontal line.

Slow metrical *stimuli*: Version 1

Slow metrical *stimuli*: Version 2

Slow metrical *stimuli*: Version 3

Fast metrical *stimuli*: Version 1.

Fast metrical *stimuli*: Version 2

Fast metrical *stimuli*: Version 3

Fast metrical *stimuli*: Version 4

Fast metrical *stimuli*: Version 5

Fast metrical *stimuli*: Version 6

Appendix C

Instructions for Participants

INSTRUCTIONS EXPERIMENT 1

Six short musical excerpts will be presented to you. All of them are played with a timbre of a piano. Some notes (isolated, or in groups of 2 or 3 notes) have a timbre of harp. You have to press the green button as quickly as possible each time you hear the harp timbre. When there are groups of 2 or 3 notes you have not to press the button for each note, only once for the entire group when you listen to the first harp note.

INSTRUCTIONS EXPERIMENT 2

Also for this experiment, you will listen to six musical excerpts with different durations while psychophysiological measures will be taken (heart rate, respiration, skin conductance and temperature). At the beginning and middle of the experiment there will be 3 minutes of silence. You have to be very quiet and relaxed during all the experiment. In particular, do not move your hand with the sensors while you hear music and in the three minutes of silence periods. After each musical fragments some questions will be asked about your experience and perception of the music. Nevertheless, the most important is to concentrate freely on the music, without thinking about the questions. The most important data are your psychophysiological measures, not your answers to the questions. There are not correct or wrong answers. All answers will be helpful to understand your perception of these musical fragments.

GENERAL INSTRUCTIONS

Both experiments will be carried out mixed. After listening to each musical excerpt of experiment 2 and answering a series of short questions, a melody of experiment 1 will be presented to you. You can ask any question during the session, except when you are listening to the musical excerpts, doing the recognition timbre task or during the silence periods.

Appendix D

Order of Presentations of Musical *Stimuli* to Participants

P1 **Exp. 2**	**NS**	NF	NS	NF	**MS**	MF
Exp. 1	MR 2	MR3	ML1	NL2	NR4	NR1
2	**NS**	NF	NS	NF	**MF**	MS
	MR3	NL2	MR2	ML3	NR1	NR4
3	**NF**	NS	NF	NS	**MS**	MF
	MR4	MR1	NR3	NR2	ML3	NL2
4	**NF**	NS	NF	NS	**MF**	MS
	ML1	MR3	NR1	NR4	MR2	NL2
5	**MS**	MF	**NS**	NF	NS	NF
	NL2	NR2	ML3	NR3	MR4	MR1
6	**MS**	MF	**NF**	NS	NF	NS
	MR3	NR4	MR1	NL2	ML1	NR2
7	**MF**	MS	**NS**	NF	NS	NF
	MR4	ML1	NL3	NR2	MR3	NR1
8	**MF**	MS	**NF**	NS	NF	NS
	MR4	ML2	NR2	NR1	NL1	MR3
9	**NS**	NF	NS	NF	**MS**	MF
	ML3	NL2	NR3	MR2	NR1	MR4
10	**NS**	NF	NS	NF	**MF**	MS
	MR2	NR1	ML2	NR3	MR4	NL3
11	**NF**	NF	NS	NF	**MS**	MF
	NR4	ML3	NL2	NR3	MR2	MR1
12	**NF**	NF	NS	NF	**MF**	MS
	NL1	MR2	NR4	ML3	MR1	NR3
13	**MS**	MF	**NS**	NF	NS	NF
	NR3	NR4	ML3	NL2	MR2	MR1
14	**MS**	MF	**NF**	NF	NS	NF
	NR2	NL3	NR1	MR4	MR3	ML1
15	**MF**	MS	**NS**	NF	NS	NF
	NR4	MR1	NL1	NR2	ML3	MR3
16	**MF**	MS	**NF**	NF	NS	NF
	ML	NR3	MR4	NR2	MR1	NL
17	**NS**	NF	NS	NF	**MS**	MF
	NR1	ML2	MR3	MR4	NL1	NR2
18	**NS**	NF	NS	NF	**MF**	MS
	MR4	NR1	ML3	NL1	NR2	MR3
19	**NF**	NF	NS	NF	**MS**	MF
	NR3	NR1	MR4	ML3	MR2	NL2
20	**NF**	NF	NS	NF	**MF**	MS
	MR1	ML1	NL2	NR4	MR2	NR3
21	**MS**	MF	**NS**	NF	NS	NF
	NR1	ML2	MR4	MR2	NR3	NL3
22	**MS**	MF	**NF**	NF	NS	NF
	MR4	NR2	NR3	MR1	NL3	ML2
23	**MF**	MS	**NS**	NF	NS	NF
	NR3	MR4	NR2	NL2	MR1	ML1
24	**MF**	MS	**NF**	NF	NS	NF
	ML3	MR2	NR4	NL2	MR3	NR1
25	**NS**	NF	NS	NF	**MS**	MF
	NL2	ML3	MR3	MR4	NR1	NR2
26	**NS**	NF	NS	NF	**MF**	MS

		ML3		NR4		MR2		NR3		NL1		MR1
27	**NF**		NF		NS		NF		**MS**		MF	
		NR2		NL1		MR4		NR3		MR1		ML2
28	**NF**		NF		NS		NF		**MF**		MS	
		NR2		ML2		MR4		NL3		MR3		NR1
29	**MS**		MF		**NS**		NF		NS		NF	
		ML2		MR1		NL1		NR4		MR2		NR3
30	**MS**		MF		**NF**		NF		NS		NF	
		NR1		MR4		ML2		NL1		MR2		NR3
31	**MF**		MS		**NS**		NF		NS		NF	
		NL1		MR4		NR3		MR1		NR2		ML2
32	**MF**		MS		**NF**		NF		NS		NF	
		NL1		NR1		ML3		MR2		MR3		NR4
33	**NS**		NF		NS		NF		**MS**		MF	
		ML2		MR1		NL1		NR2		MR4		NR3
34	**NS**		NF		NS		NF		**MF**		MS	
		ML2		NL1		NR2		MR3		NR4		MR1
35	**NF**		NF		NS		NF		**MS**		MF	
		MR4		MR2		ML3		NR3		NL2		NR1
36	**NF**		NF		NS		NF		**MF**		MS	
		NL1		ML3		MR1		MR2		NR4		NR3
37	**MS**		MF		**NS**		NF		NS		NF	
		NR1		MR4		MR3		NR2		ML1		NL2
38	**MS**		MF		**NF**		NF		NS		NF	
		ML1		NR4		NL3		MR2		NR3		MR1
39	**MF**		MS		**NS**		NF		NS		NF	
		MR4		ML2		NR2		NR3		MR1		NL1
40	**MF**		MS		**NF**		NF		NS		NF	
		MR1		NL1		NR4		ML3		NR2		MR3

Note: MS = Metrical slow *stimuli* of Experiment 1

NS = Non-metrical slow *stimuli* of Experiment 1

MF = Metrical fast *stimuli* of Experiment 1

NF = Non-metrical fast *stimuli* of Experiment 1

ML = Metrical slow *stimuli* of Experiment 2

NL = Non-metrical slow *stimuli* of Experiment 2

MR = Metrical fast *stimuli* of Experiment 2

NR = Non-metrical fast *stimuli* of Experiment 2

The number attached to the letters for the Experiment 2 indicates the number of version of changes of timbre.

Appendix D

Questionnaire Experiment 2:

Subjective Experience and Duration Estimated of Musical Excerpts

Indicate with a cross in the scales from 1 (nothing) to 7 (very) the levels of:	1	2	3	4	5	6	7
Familiarity with the music							
Pleasantness caused by the music							
Absorption with the music (1, nothing absorbed; completely absorbed)							
Complexity of the music (1, very simple; 7, very complex)							
Dynamism of the music (1, static; 7 very active or dynamic)							

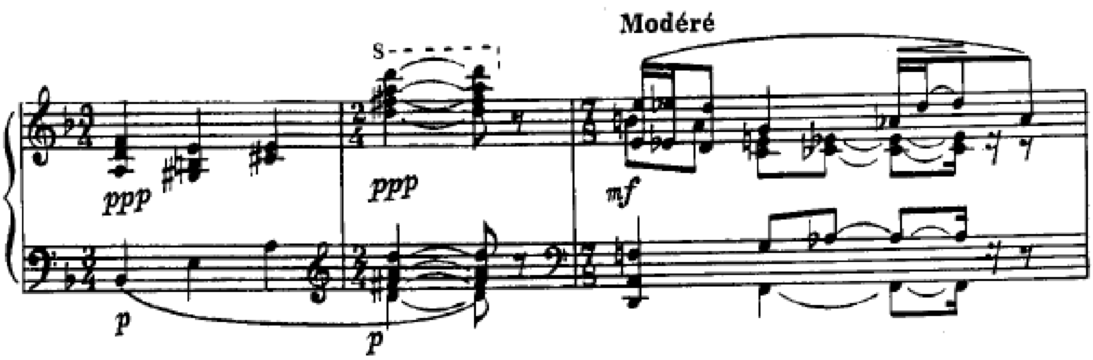
Mark with a vertical line in the scale your estimated duration of this fragment (from 0sec. to 5 minutes):

Note: The line was 25 cm. in the sheets for participants.

Appendix D

Scores of the musical pieces of Experiment 2

Messiaen. *Préludes pour piano: 4. Instants défunts* (Dead instants).




mf
pp
pp
Lent
ppp
expressif
mf
ppp
p


Modéré
ppp
p
pp


Retenu
Modéré
mf
pp
Lent
pp
ppp
expressif
mf
plus p
Toujours lent
ppp
encore plus p
p
ppp

Messiaen : *Catalogue d´oiseaux. Livre 5: VIII. L'Alouette calandrelle*. (Bird Catalogue: Book: Short-toed Lark).


Faucon Crécerelle
Vif (♪ = 152)
mf
f
(sans péd.)
Caille
Très modéré (♪ = 120)
(bien rythmé, claquement doux et mouillé)
long
mf
Vif (♪ = 152)
p
(sans péd., avec sourdine)
m.g. dessus
Alouette Calandrelle
Un peu vif (♪ = 108)
Vif (♪ = 160)
p
mf
Un peu vif (♪ = 108)
Vif (♪ = 152)
m.d. dessus

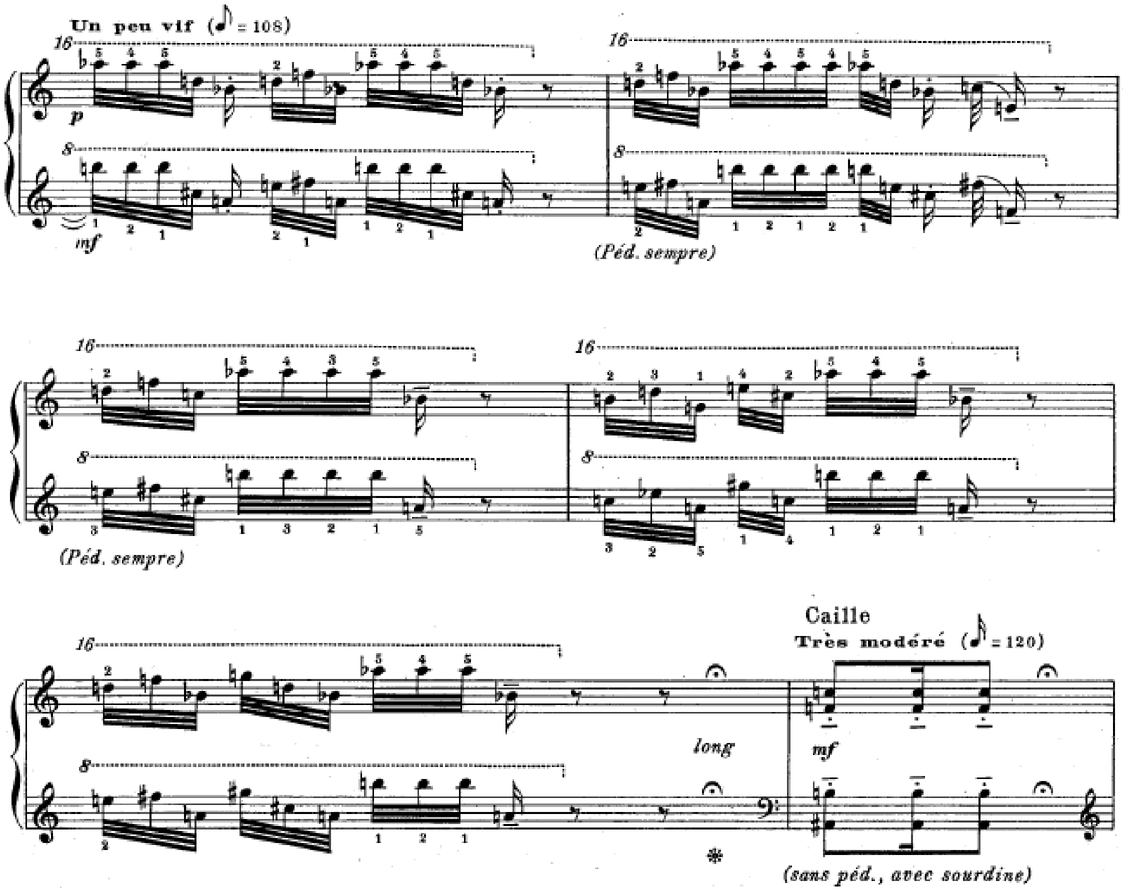

Un peu vif (♪ = 108)
Vif (♪ = 160)
(m.d. dessous)
(m.g. dessus)
Un peu vif (♪ = 108)
Vif (♪ = 160)
m.g. dessus
Un peu vif (♪ = 108)
long
Alouette Calandrelle
Presque vif (♪ = 132)
Cochevis huppé


d. dessus
(g. dessous)

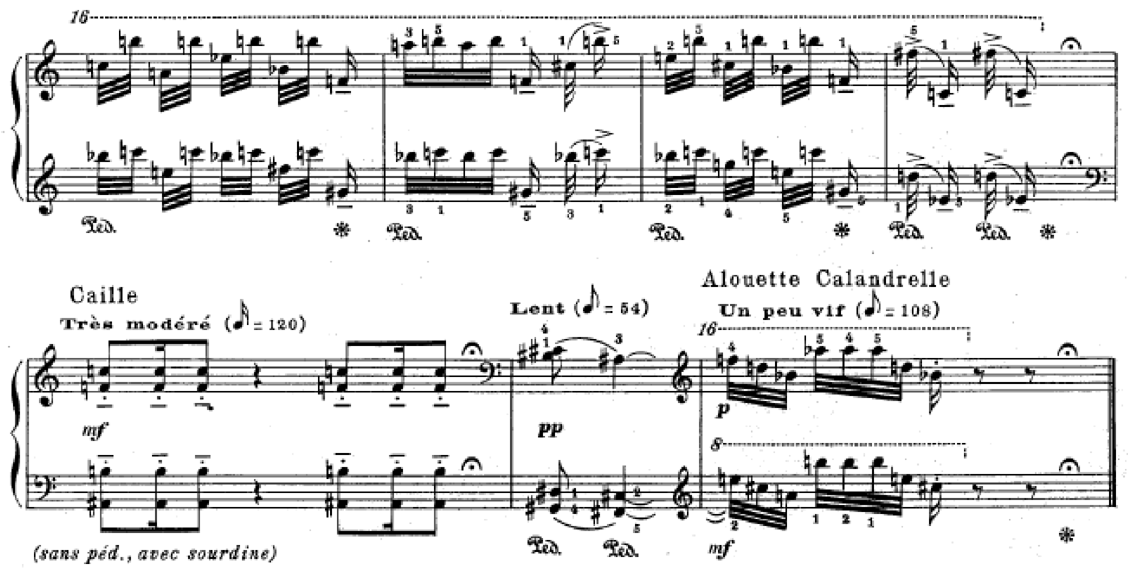

Vif (♪ = 160)
long
Alouette Calandrelle
Un peu vif (♪ = 108)
Vif (♪ = 160)
(Péd. sempre)
Un peu vif (♪ = 108)
Vif (♪ = 160)
m. g. dessus
(Péd. sempre)
Un peu vif (♪ = 108)
Vif (♪ = 160)
m. g. dessus


Un peu vif (♪ = 108)
Vif (♪ = 160)
Un peu vif (♪ = 108)
più f
Vif (♪ = 160)
(m. d. dessus)
(m. d. dessus sempre)
Un peu vif (♪ = 108)
long
(m. g. dessous)
(m. g. dessous sempre)
(chœur des cigales)
Presque vif (♪ = 138)
mf (sec et monotone)
pp
cresc.
sans péd.
cresc.
sans péd.
Faucon Crécerelle
Vif (♪ = 152)

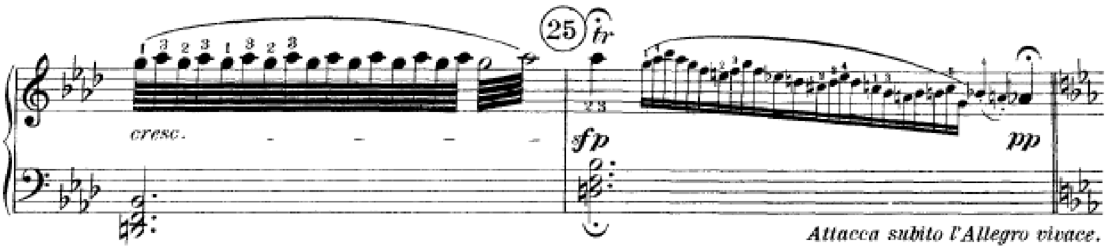

Caille
Très modéré (♪ = 120)
mf (bien rythmé, claquement doux et mouillé)
(sans péd., avec sourdine)
(chaleur et solitude
du désert de la Crau)
Lent (♪ = 54)
long
pp
Alouette Calandrelle
Un peu vif (♪ = 108)
p
mf (clair)
Lent (♪ = 54)
Un peu vif (♪ = 108)
Lent (♪ = 54)
Un peu vif (♪ = 108)
(Péd. sempre)


Un peu vif (♪ = 108)
(Péd. sempre)
(Péd. sempre)
long
Caille
Très modéré (♪ = 120)
(sans péd., avec sourdine)


Alouette des champs
(jubilation véhémente)
Vif (♪=152)
16
ff
f
Ped.


Caille
Très modéré (♪ = 120)
Lent (♪ = 54)
Alouette Calandrelle
Un peu vif (♪ = 108)
(sans péd., avec sourdine)

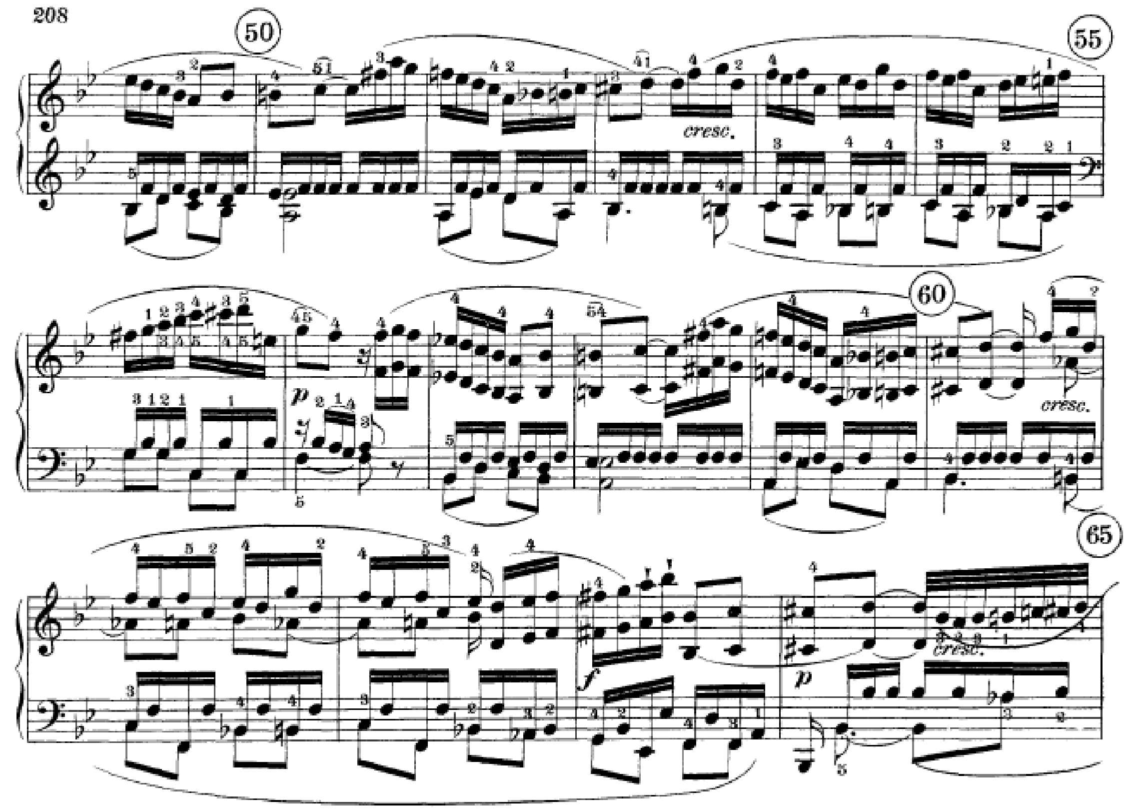
Beethoven. Piano Sonata no.13 in E flat major, op. 27 no.1, III. *Adagio con espressione – attacca.*



Beethoven. Piano Sonata no.11 in B flat major, op. 22. IV. *Rondo. Allegretto.*

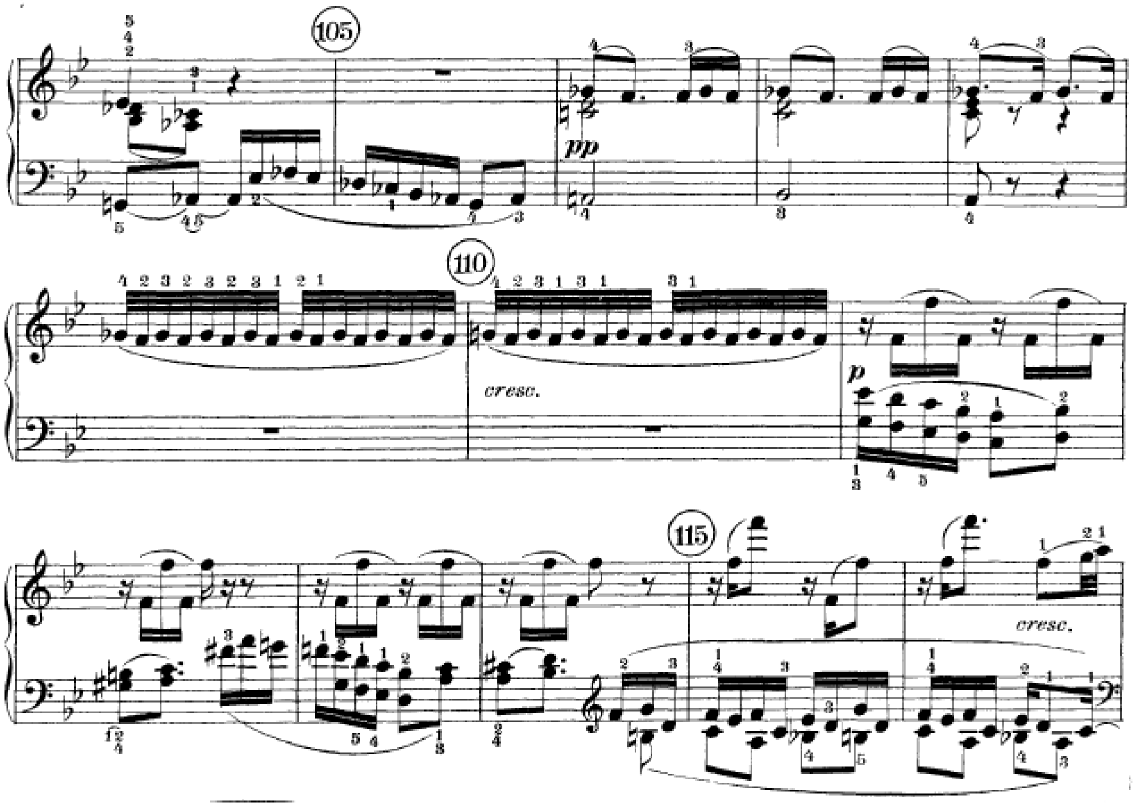

20
p cresc.
p cresc.
2) The turn is to be played before the dotted 16th c³.
cresc.
fp
35
cresc.

1) Recent editions make an analogy with m 33, but an octave higher 2) With Nachschlag




70
75
cresc.
80
85
90


95
100
cresc.


105
110
115
cresc.
cresc.


120
cresc.
125
cresc.
130
135
p cresc.
p cresc.
140


145
cresc.
fp
cresc.
150
sf
p
tr
155
pp
160
p
165
cresc.
sf
p


cresc.
170
cresc.
175
cresc.
180
cresc.
tr
185


190
cresc.
cresc.
195
pp