TEMPORAL AND STRUCTURAL PERCEPTION OF RHYTHMIC IRREGULARITIES

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TEMPORAL AND STRUCTURAL PERCEPTION OF RHYTHMIC IRREGULARITIES

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ABSTRACT

TEMPORAL AND STRUCTURAL PERCEPTION OF RHYTHMIC IRREGULARITIES

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Time perception studies often seek for a timing mechanism that can explain temporal judgments in a general way. In search of such a model, environmental, contextual and subjective factors affecting temporal judgments should be taken into account as well. The present study provides a critical evolution of existing timing models by comparing the interval processing and production strategies of musicians and non-musicians. The study contains 2 experiments: Experiment 1 is a perceptual comparison task and Experiment 2 is a rhythm reproduction task. The contrasts between the two groups are believed to be captured by participants' initial reactions to rhythmic structures. For that purpose, short scale (4 beat) rhythmic samples are used in the experiments. Standard samples are regular 4 beat rhythms. Test samples include regular and irregular rhythms. The irregular conditions are prepared by changing the temporal position of the second beat of the regular rhythms. Early and late second beats in these irregular samples have the same temporal distance from the expected beat. Hence, the expectancy violation reflects any differences between early and late oddball stimuli. The experimental analyses suggest an asymmetry between early and late oddballs in participants' initial reactions to such expectancy violations, in terms of their perceptual comparison of rhythms, as well as their duration and rhythm (re)production. Moreover, it provides evidence for different memory procedures and encoding strategies used by participant groups in order to cope with rhythmic irregularities.

Keywords: Time cognition, rhythmic irregularity, expectancy violation, oddball stimulus

ÖZ

RİTMİK DÜZENSİZLİKLERİN ZAMANSAL VE YAPISAL OLARAK ALGILANMASI

Bostancı, Çağdaş

Yüksek Lisans, Bilişsel Bilimler Bölümü

Tez Yöneticisi: Yrd. Doç. Dr. Annette Hohenberger

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Zaman algısı ile ilgili çalışmalar, zamansal yargıların oluşturulmasını genel olarak kapsayacak bir zamanlama mekanizması arama eğilimindedir. Böyle bir model oluşturulurken, bu yargıyı etkileyen çevresel, içerikle ilgili ve bireysel etkenler de dikkate alınmalıdır. Bu çalışma, müzisyen ve müzisyen olmayan katılımcıların kullandığı zamanlama stratejilerini karşılaştırarak, mevcut zaman algısı modellerinin kritik bir incelemesini sunar. Çalışma içerisinde 2 deney bulunmaktadır: Deney 1 algısal karşılaştırma ve Deney 2 duyulan ritmin yeniden üretimini içerir. Katılımcıların dinledikleri ritmik yapılara karşı ilk reaksiyonlarının, katılmcı gruplar arasındaki farkları göz önüne sereceği düşünülmektedir. Bu amaçla, deneylerde kısa zamanlı (4 vuruşluk) ritim örnekleri kullanılmıştır. Bu test örnekleri düzenli ve düzensiz ritimlerden oluşmaktadır. Düzensiz ritimler, düzenli ritmin ikinci vurşunun zamansal konumu değiştirilerek elde edilmiştir. Oluşturulan erken veya geç ikinci vuruş ritim örnekleri, beklenilen vuruşa zamansal olarak eşit uzaklıktadır. Dolayısıyla, erken ve geç beklenti ihlalleri arasındaki farkların bu şekilde ortaya çıkarılabileceği düşünülmektedir. Deney analizleri, katılımcıların ilk reaksiyonlarında erken ve geç beklenti ihlalleri arasında bir asimetri olduğunu desteklemektedir. Ayrıca, ritmik düzensizlikler karşısında, katılımcı grupların değişik hafıza prosedürleri ve algısal kodlama stratejileri kullandığına dair kanıtlar da bulunmuştur.

Anahtar Sözcükler: Zaman algısı, ritmik düzensizlikler, beklenti ihlalleri, beklenmeyen uyaran

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LIST OF ABBREVIATIONS

AGM: Attentional Gate Model

BOLD: Blood Oxygen-Level Dependent

DAT: Dynamical Attending Theories

EEG: Electroencephalography

fMRI: Functional Magnetic Resonance Imaging

IOI: Inter Onset Interval

LTM: Long-Term memory

PL: Phonological Loop

RT: Response Time

SET: Scalar Expectancy Theory

STM: Short-Term Memory

VSSP: Visuo-Spatial Sketch-Pad

WM: Working Memory

CHAPTER 1

INTRODUCTION

Objectively time passes at a steady pace, uninterruptedly. Although this conception may be altered in subjective perception of time, fundamental properties of the human mind such as reasoning and planning are based on this objective assumption. In that sense, time is essential in attributing meaning to the environment. When events unfold in time they create temporal patterns. The figural properties of such patterns depend on the proportion of involved intervals with respect to each other. However, the precise timing of events is not necessarily included in such information. Supposedly the real time unfolding of patterns is under the influence of environmental and contextual components. Additionally, cognitive factors such as emotional states, attentional load, perceptual properties etc. are known to be effective on time perception (Zakay & Block, 2004). This inadequacy in providing an objective account of time necessitates explicit reference points to implicate precise temporal information. The solar calendar system illustrates a good example of organization of time by human being: depending on the recursive cycles in the solar system, creating equally divided temporal spans that are hierarchically nested into each other.

The same form of hierarchical organization of time is also used in musical notation. Rhythmic part of the music can be expressed by indication of allowed number of notes in a measure, the values of individual notes and the tempo. This study concerns with the cognitive mechanisms responsible for perception of rhythmic structures in terms of their figural and temporal properties. One of the purposes of the study is investigating the differences between regular and irregular rhythms in terms of their mental representations. The existing literature provides conflicting ideas concerning the representations of the regular and irregular rhythms. Povel and Essens (1985) argue that regular rhythms are encoded through an internal clock mechanism based on the distribution of accented events, while as the rhythmic complexity increases figural encoding becomes effective. Handel (1998) rejects the inclusion of a clock unit in perception of rhythmic structures and claims that only figural properties are effective in their representations. Another account is proposed in Dynamical Attending Theories (DAT), suggesting a unitary mechanism for temporal and figural representations through entrainment (Jones, 2009). The present study creates a testing environment for these conflicting ideas by introducing the same rhythmic samples successively after a regular standard and also individually in separate experiments. The results are discussed in terms of the varying temporal judgments made with and without an external clock.

The irregular rhythms used in the experiment are produced by changing the temporal position of a metronome like, equal interval rhythm (regular). Two irregular samples were created by changing the second note of the regular samples. In the early note sample the second note is heard 1:3 regular interval before the expected note and in the late note samples this note is heard 1:3 regular interval after the expected note. This way the irregularity is restricted with the temporal position of the second note, and a possible asymmetry of early and late oddball is investigated. The outcomes of this manipulation are compared in terms of the internal clock argument with respect to clock-counter theories (Grondin, 2010) and dynamical account of temporal perception (Jones, 2004). The observed asymmetry among the regular, early note and late samples indicates a possibility for the co-existence of different mechanisms and provides a detailed analysis of linear (Treisman, 1964) and non-linear clock hypotheses (van Rijn & Taatgen, 2008) and the metric binding hypothesis (Jones, 2009).

The experiments are conducted between musician and non-musician groups. The literature provides evidence that the musicians tend to focus on figural aspects of rhythms and underestimate the temporal duration, while non-musicians oppositely try to encode real-time durations and represent the patterns poorly (Hébert & Cuddy, 1998; Yee, Holleran, & Jones, 1994). The outcomes of the experimental analysis confirms this proposition and adds that temporal representations are kept for both groups as a limiting factor, concerning the total duration of the rhythmic samples. Between groups analysis is applied to all above mentioned arguments and different profiles are provided for musicians and non-musician groups. Moreover, contribution of musical training to utilization of the presented mechanisms and representation strategies are included in the discussion.

The study also covers a categorization of influential factors in rhythm perception, according to the memory related procedures and encoding strategies. These categorization includes a review of the literature on cognitive and computational models of memory and time perception. Baddeley's (2012) Working Memory model and its possible application to music cognition is used as an illustration of parallel operation of pattern representation and time keeping mechanisms. The information storage principles of the involved units are evaluated according to computational models of Salvucci and Taatgen (2008) and J. Borst, Taatgen, and Rijn (2014). Additionally, the memory pool model of Taatgen and van Rijn (2011) and the memory contamination effect traced in the results of the experiments.

The experimental study was conducted as two tests. Experiment 1 contains a perceptual comparison test, where total duration of the test samples are compared with a standard. In Experiment 2, participants reproduced these same samples in their respective sequential order. The test samples are short tracks consisted of four notes. The reason for using such short samples was to reveal strategical approaches of the participants at the beginning of the presumed adaptation processes and also to provide an insight concerning the utilized mechanisms. Also, 4:4 is a very common measure used in Western music and four notes were considered to be the minimum meaningful unit of this measure. This is a novel approach and produced some interesting outcomes. One of the novel findings of the study is the perseverance of the total duration of samples as a limiting factor regardless of the rhythmic structure.

This effect is deemed to be restricted with short samples, and there are no test conditions to specify any threshold as to maximum number of notes for this factor to be effective. Moreover, the structural conditions are also limited with the abovementioned regular and irregular samples used in the experiments. Another novel finding of the study is the asymmetry between early and late conditions. Although such asymmetry was reported in the literature (Terry, Stevens, Weidemann, & Tillmann, 2016), detection of conditions influencing this asymmetry as a between groups variance is believed to make a contribution to the existing discussion. Also these findings support the possibility of co-existence of different timing mechanisms. The scope of the study is not adequate to confirm this hypothesis, but it is proposed as a possible research question in the future studies. The following section includes a review of the literature on the mentioned memory models, rhythm perception theories and timing mechanisms.

CHAPTER 2

LITERATURE REVIEW

In cognitive science, time perception is often related with the properties of a memory unit and a timing mechanism. The memory models can be basically divided into two groups, modular systems with executive attentional control and memory pool models that describe certain procedures concerning the interactions among the stored items. Below section includes Baddeley's (2012) Working Memory model to provide a background for illustration of processing of rhythm perception in different modules. Additionally, other multiple source models of Short-Term Memory (STM), which predicts an unsupervisory interaction among stored items are revisited. Also, clock-counter models and Dynamical Attending Theories (DAT) will be reviewed as different models of internally induced time keeping mechanisms. The remaining of the chapter specifically investigates cognition of musical time with respect to temporal and figural encoding. Related theories will be summarized in terms of their prediction concerning which strategy is used in which situations.

2.1. Short-Term Memory (STM) Models

2.1.1. The Working Memory Model

The Working Memory Model was first introduced by Baddeley & Hitch in 1974. The model basically is a limited capacity modular system that separates temporary storage (short-term memory) and attentional control units (A. Baddeley, 2012). The final version the model contains a central executive and three temporary storage units: phonological loop, visuo-spatial sketch-pad (VSSP) and episodic buffer (Figure 1). VSSP illustrates a dissociation between visual and spatial perception (A. Baddeley, 2012). According to purposes of the study, this unit will not be reviewed further. The phonological loop component stores and maintains the information gathered from vocal or subvocal rehearsal (A. Baddeley, 2012). The information held in this unit has a limited span and decays in time. Nevertheless, phonological similarities between sequential events decrease the amount of retrieved information, while distinct events are subject to the capacity and delay constrains. This similarity effect is an automatic STM mechanism according to Repetition Suppression Paradigm, which provides evidence that neuron groups gradually decrease the energy

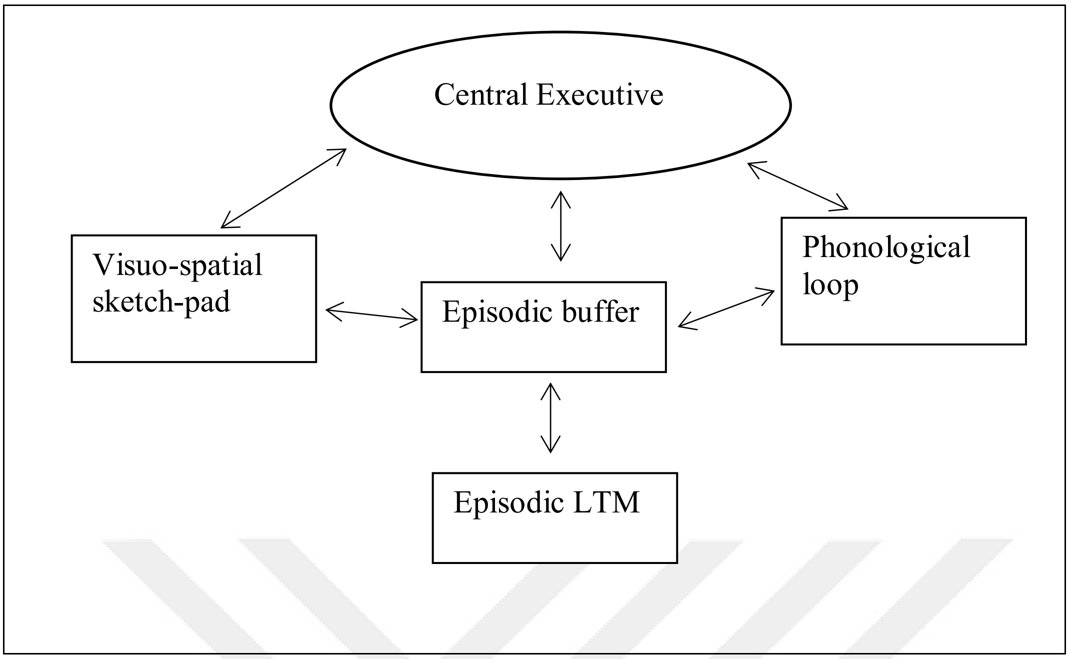

Figure 1. *Short-term components of Alan Baddeley's Working Memory Model*

directed to repeating stimuli (Barron, Garvert, & Behrens, 2016). The phonological loop retains serial order (A. Baddeley, 2012). Baddeley offers two different possible mechanisms for storage and retrieval of data ordering information. First category includes dynamical representation of this data via oscillatory patterns or network models (D. A. Brown, Preece, & Hulme, 2000). Second mechanism assumes a decline in attentional energy over time, suggesting a primacy effect in activation strength (D. M. Eagleman & Pariyadath, 2009). As Baddeley (2012) notes these theories do not depend on chaining of events. Instead of chaining, he favors a chunking system to explain phenomenon such as easier retrieval of meaningful sentences in comparison to scrambled words (Cowan, 2010). The phonological loop is also associated with music cognition, but some studies demand a revision of this unit by adding an extra storage dedicated to music perception (Thompson & Yankeelov, 2012). On more thing to add in phonological loop is the articulatory suppression effect that spoken or subvocalized items gains obligatory access to phonological store and drops the performance of processing another concurrent phonological/auditory information, if they are contextually similar (A. Baddeley, 2012). The articulatory suppression also observed to be effective in rhythm perception that subvocal rehearsal –or by the same account tapping as a motor planning of upcoming events- leads to a mental control over rhythmic capacities, while they negatively influence processing of similar concurrent stimuli with different contexts (Pich, 2000).

Baddeley (A. D. Baddeley, 2007) summarizes the functions of the central executive unit as "…capacity to focus attention, to divide attention, switch attention and provide a link between working memory and long-term memory". The proposed attentional control unit has an explanatory power for the existing time perception theories reviewed below and provides a theoretical account for investigating concepts such as interval timing, multi-tasking and temporal perception as a secondary task. On the other hand, memory pool arguments reviewed below provides a simpler explanation concerning assimilation of the perceived intervals by accounting an unsupervised interaction between memory items.

The last unit of the working memory model is the episodic buffer. It is defined as a limited capacity buffer that links WM and LTM and also VSSP and PL units, as it can represent multi-dimensional information (A. Baddeley, 2003). Episodic buffer is associated with retrospective temporal judgements (Zakay & Block, 2004). Retrospective judgments can be made via contextual associations to judge the recency of events (location) or estimation of the distance between a past event and the present or between two past events (Grondin, 2010). In that sense, episodic memory plays a crucial role in reproduction of a past duration. In laboratory conditions, participants of the retrospective paradigm experiments are not informed beforehand that the task in hand requires temporal judgements (Grondin, 2010). On the other hand, prospective temporal judgements help in making future plans and executing them on a specific point in time or specific duration (Düzcü & Hohenberger, 2014). Accordingly, in prospective paradigm participants know that they will be asked to produce temporal judgements (Grondin, 2010). Different models also argue that episodic buffer may as well be included in the prospective temporal judgements (J. P. Borst, Taatgen, & van Rijn, 2010).

2.1.2. Multiple Resources Theories

Baddeley's executive control component represents a single unit that is responsible for organizing allocation of attention (A. Baddeley, 2012). By the same account, Treisman (1964) offers a selective attention property of cognition that irrelevant information is attenuated –irrelevant stimulus is not blocked but given no resources. This type of selective attention mechanisms are generally called as bottleneck theories (Ruthruff & Pashler, 2010). The multiple resource theories on the contrary, as explained by Wickens (2008), propose a model consisting of distinct resource pools for different operations. His model includes four dimensions: stages of processing, codes of processing, modalities dimension and visual channels. Basically the model proposes a separated shot-term memory that categorizes the information according to its quality (perceptual or cognitive), stimulus codes (visual, linguistic etc.), perceived modality and the visual property (focal or ambient). Although it seems like a more fractioned version of Baddeley's model, this model tries to remove the homunculus of the central executive. It identifies when an executive mechanism engages in an information processing system according to a time sharing factor via resource demands and conflicts (Wickens, 2008). In other words, presentation sequence and the properties of the stimuli determine the information processing stage, without necessitating an executive unit or selective attention mechanism.

Salvucci & Taatgen (2008) propose another unsupervisory computational mechanism in their Threaded Cognition model. This model assumes that separate information processing channels have distinct "mental" sources (vision, memory etc.). These channels may work in parallel in case there are no conflicting operations –if the same information is not needed by distinct operations. When there is a conflict, a central unit carries out resource acquisition and conflict resolution, which does not display the full supervision intended in executive control. Both the resources and the central unit are work with bottleneck principles, so while the same resource can be used for two different simultaneous operations, parallel operations cannot be directed to the relevant goal mechanism at the same time. Later, a third module, a problem state bottleneck was added into this model (J. P. Borst et al., 2010). The need for this module arouse as the limitations of the goal resources cannot be defined in their model (J. Borst et al., 2014). The problem state buffer includes an intermediate mental representation of the problem in hand, every resource includes one of these buffers and it can hold one chunk of information at a time. However, they note that not all tasks need a problem representation, if they don't need intermediate representations or they are present in the real world. Authors also noted that the problem state resource resembles to Baddeley's episodic buffer that stores information for instant use, which also includes prospective temporal judgments.

In summary, Baddeley's WM model provides a possible foundation for a musical module within the phonological loop unit. The proposed storage and retrieval strategies discussed therein might provide a ground for interpreting the data concerning the interval representation of the participants in the experimental study. Also, the role of a possible executive attentional control unit will be investigated for both participant groups in comparison to the mentioned multiple resource theories without executive control. Lastly, the possible role of the episodic buffer in pattern recognition (J. Borst et al., 2014) will be investigated in consideration with how musical expertise facilitate utilization of possible WM models.

2.2. Timing Models

Internal clock theories can be considered as extensions of a general memory model which specifically concerns with encoding of the temporal data. Such models usually seek for isolating the temporal data processing from other mental operations. In that sense, they are useful in categorizing the temporal data and specifying its interactions with other perceptual information. The idea of an "internal" clock particularly entails a cognitive representation. The clock-counter models argue that such internal representations of time are formed by mapping the current flow of events into a clock mechanism that works independently. The other model to be reviewed is the entrainment model, which defends that the temporal information is gathered by stimulus specific adaptation through self-organizing neural oscillations.

2.2.1. Clock- Counter Models

The idea of an internal clock started with models containing a clock device that arbitrarily emits pulses and a counter that receives these pulses and produces an output as a measure of passed time (Zakay & Block, 1995). The real challenge of these models is to discover the factors that influence the pulse transmission between the clock and counter units. Scalar Expectancy Theory illustrates a switch between the pace-maker and accumulator, which is influenced by the devoted attention to passage of time (Figure 2) (Graf & Grondin, 2012). The accumulator emits regular pulses at a fixed rate. When the attention is focused in time the switch closes and pulses are received by counter, when less attention is directed towards time the switch opens and signals become weaker or not transmitted at all. The reference memory is a long-term memory component that contains experienced durations. The contents of reference memory are compared with the working memory input via a series of arithmetic operations over the means of presented durations and positive correlation of the means estimate and its standard deviation represents the scalar property (Weber's Law) (Graf & Grondin, 2012). SET is known to be effective in animal timing and its' basic working principles has been adopted by the Attentional Gate Model (AGM).

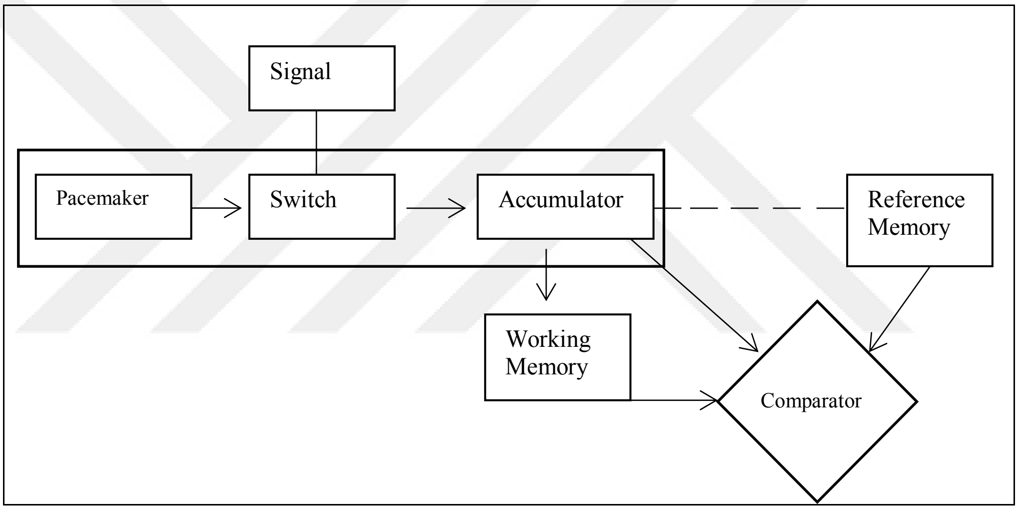

Figure 2. *SET Model of time perception.*

Attentional Gate Model (AGM) changes the switch to operate in all-or-none fashion that closes and transmits the pulses if temporal information is to be produced (Zakay & Block, 1995). In that sense, the switch closes when prospective judgments are to be made. The model contains a gate before the switch that controls the flow of pulses between pace-maker and accumulator. The gate is opened or closed according to the attention allocated for time perception (Zakay & Block, 1995). This property especially makes the AGM preferable in evaluating the effects of secondary task demands in time perception. In a version of the model, the gate is altered with Baddeley's executive control unit which resulted in Executive-Gate Model (Block, Hancock, & Zakay, 2010).

Van Rijn & Taatgen (2008) developed the SET model into a different framework to explore the nature of multiple timing. They proposed a single pace-maker and accumulator model that can be accounted for processing multiple intervals if the intervals start at the same time. In this model, the abovementioned scalar property arising from the Weber's law is contingent upon the non-linear (gradually increasing) nature of the emitted pulses and linear increase of the accumulator. This way a single clock can be accounted for multiple timing by dividing the intervals into smaller pieces and operating simple arithmetic upon the mean estimations of experienced durations (van Rijn & Taatgen, 2008).

2.2.2. Memory Pool Model

Memory pool models are specifically interested in storage and retrieval of the temporal information. One computational model is developed by Taatgen & van Rijn (2011) that focuses on mental representations of interval durations and interaction between these representations in multiple timing tasks. This model included in the timing mechanisms, because it describes the timing mechanism through a memory model, with no encoding effect. They present a memory pool model, where no solid representations are formed. Moreover, these interval representations may influence each other but recent memories and elements matching with the current state of the system have stronger activation rate. They argue that their model is quite flexible to adopt any situation, in which a model with solid representation of memory items would be unexplanatory. While this is a general proposition, they explicitly refer to multiple timing tasks (Taatgen & van Rijn, 2011).

2.2.3. Entrainment Model

Dynamical Attending Theories (DAT) provides an alternative approach to resource theories of attentional allocation (Barnes & Jones, 2000). Accordingly, Barnes & Jones (2000) argue that resource theories focus on allocation of attention to time in presence of a secondary task, but they cannot account for attention in time, thus are not sensitive to environmental properties of contextual stimulus patterns such as rate and rhythm (actually as stated above the resource pool model of Taatgen & van Rijn (2011) provides an account on this phenomenon in a later study). DAT introduces an entrainment mechanism that synchronizes to unfolding of events through neural oscillations. The attentional energy fluctuates and creates peak points of attention, and synchrony occurs when these peak points coincide with the stimuli. This means that the system has a reliable expectancy profile and the attentional energy is narrowed. When the expectancy profile is unclear –no contextual representation is present- the attentional energy widens. According to Jones (2004) adaptation to a rhythmic pattern occurs in two dimensions: period adaptation (adaptation to global events) and phase adaptation (adaptation to local events) (Figure 3). Period adaptation is a slow process, which according to Jones (2000) has little effect in the synchronization process, but illustrates a global representation of the temporal event structure. On the other hand, phase adaptation is a rapid process that each event updates the expectancy profile until adaptation is achieved. The nature of these updates is non-linear and oriented in the expectancy point (attractor). In that sense, it resemble to the resource pool theory of Taatgen and van Rijn (2011) with an encoding account. However, instead of the mentioned contamination effect, DAT proposes a mechanism that is a dynamical system that aims to reach a goal state by adapting to real-time unfolding of events. Capacity and limitations of the entrainment mechanism will be discussed at the rhythm cognition section below.

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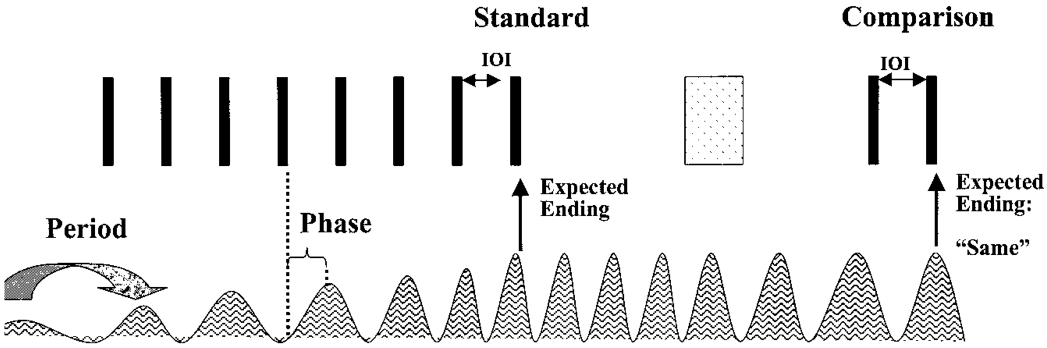

Figure 3. *The entrainment mechanism in Dynamical Attending Theories (Jones, 2004).*

2.3. Musical Rhythm

The tonal Western Music divides rhythm into two parts: grouping and meter (Lerdahl & Jackendoff, 1983). Grouping refers to emergent rhythmic patterns. Lerdahl & Jackendoff (1983) defines grouping as a recursive activity due to application of global rules of allowance over a non-overlapping hierarchical structure, which may lead to infinite repetition/progression of a pattern at different levels by using the same rules. Moreover, grouping ideally necessitates a shared grid structure to form a context and this context basically allows a serial perception, where non-adjacent units cannot be grouped together. Another basic concept of the rhythm is the accents. Accents may refer to perceptually/emotionally salient events. According to Lerdahl and Jackendoff (1983), accents may occur due to contextual musical events such as attack points, sudden changes etc., melodic/harmonic movements or distribution of beats. Concerning the rhythm, they note that listeners try to match the contextual flow with an appropriate metric system, and if no match is obtainable rhythmic complexities occur. These complexities can be observed in non-linear temporal patterns such as syncopation –strong events (accents) coinciding with weak positions (Fitch & Rosenfeld, 2007) and polyrhythms –simultaneous introduction of two conflicting rhythms (Handel & Oshinsky, 1981).

Metric structure is an artificial concept that fits into a rhythmic sequence by dividing it into equal parts and imposing hierarchical levels that are embedded into each other as linear variations of these equal interval units (Lerdahl & Jackendoff, 1983). The starting point of these levels are called beats, which Lerdahl and Jackendoff (1983) define as geometrical points in a temporal structure without a temporal span. Metric system is inherently periodic; if a beat is felt strong at a level, it is a beat at an upper level as well (Lerdahl & Jackendoff, 1983). When accents coincide with beats the metrical structure is deemed to be strong, while beats coinciding with unaccented events weakens the meter (Povel & Okkerman, 1981). However, actually meter is not an indispensable component of rhythm, and various studies report that in certain types of ethnic music performed in other parts of the world a sensation of beat is created in weak metric structures, where no beat-based periodicities are present (London, Polak, & Jacoby, 2017).

2.3.1. Temporal Encoding

Cognition of rhythm can be approached from two perspectives; emergent grouping patterns and temporal representation of events. The former depends on pattern recognition, one of the basic abilities of human mind that can be observed in various phenomenon in linguistics, visual cognition etc.. As mentioned above, rhythmic structures can display figural relations even if they lack a metric interpretation. In that sense, rhythmic pattern recognition is an automatic process that does not necessarily require a conscious evaluation. Although rhythm is deemed to bear non-linguistic meaning, it may differ according to cultural or individual differences (Stevens & Byron, 2014). In the end, all there is to be meaningful in a rhythmic pattern is the division of the intervals in a coherent way. In the following of this section, the literature on figural and temporal perception of rhythm will be reviewed.

Povel and Okkerman (1981) conducted a series of experiments in order to find how temporal structure of rhythmic patterns effect their perception. They found out that in a sequence of equitonal notes, the note with longest time span is heard as accented. Indeed, this effect is related with the grouping of notes, and should the between group intervals are longer than IOI length within the groups, the last notes of the groups are heard as accented –in the literature referred as subjective accents. They interpreted this perceptual outcome as a processing overlap in the echoic memory that notes with interval values below approx. 150 ms are not processed properly compared to notes with higher values (i.e. the last note of a group), hence the last note processed better and perceived stronger (Povel & Okkerman, 1981). This study is interesting as it shows that temporal structure of rhythmic elements can also affect their figural representation.

In a later study Povel and Essens (1985) proposed an internal clock model that detects the temporal structure of rhythmic structures according to distribution of the accents (subjective and objective) and the groupings made in connection. They defend that the clock only operates when the temporal representation of the rhythm can be produced. In other cases, where the rhythm is too complex to represent temporally (weak metric structures with syncopated accent distribution), another strategy is employed which they called figural encoding (Povel & Essens, 1985). This change in strategy according the complexity of the task can be interpreted as the switch mechanism in SET, with a new property that it opens when no representation can be formed due to complexity.

Handel (1998) revisited the temporal encoding phenomena, and by using weak and strong rhythms that show similar patterns displayed an alternative view that metric structure has little effect on perception of rhythms. Instead he argued that perceptual phenomenon such as similarity, symmetry and god continuation are effective in rhythm perception.

Finally on the role of temporal encoding in rhythm perception, Hébert and Cuddy (1998) came up with conclusion that a metric detection strategy and also absolute time encoding is effective in perception of temporal patterns. They proposed that absolute timing between group intervals are effective in pattern discrimination, while the changes in this between groups duration according to presentation rate of the within group IOIs lead discrepancies in the rhythmic context. Their results, although goes parallel with study of Povel and Essens (1985), they defend the opposite idea that figural encoding might be developed via musical training and absolute time encoding is a strategy employed by novices when they encounter a complex rhythmic structure.

2.3.2. Dynamical Account of Rhythm Perception

Jones (2009) adapts a unified account of rhythm perception through entrainment mechanism. She argues that entrained neural activations oscillate at stable frequencies that peak points of harmonic temporal durations (e.g. 200ms, 400ms, 800ms, 1600ms) coincide and adaptation to such intervals can be carried out via routine phase adjustments (Figure 4). This model, which she calls Metric Binding Hypothesis (2009), is inherently metric as it readily creates an expectancy profile of the metric accents upon introduction of the stimuli. This expectancy profile dynamically represents the rhythmic context, once entrainment is achieved. Entrainment of multiple oscillations results in resonance and it brings an explanation for multiple timing tasks; harmonic durations that have a temporal span expressed as power of the smallest grid can be processed together with little effort. For more complex rhythms, training should improve the chance of achieving resonance, otherwise she discusses that intervals with conflicting duration (e.g. 600ms compared to above intervals) degenerate towards the expectancy point.

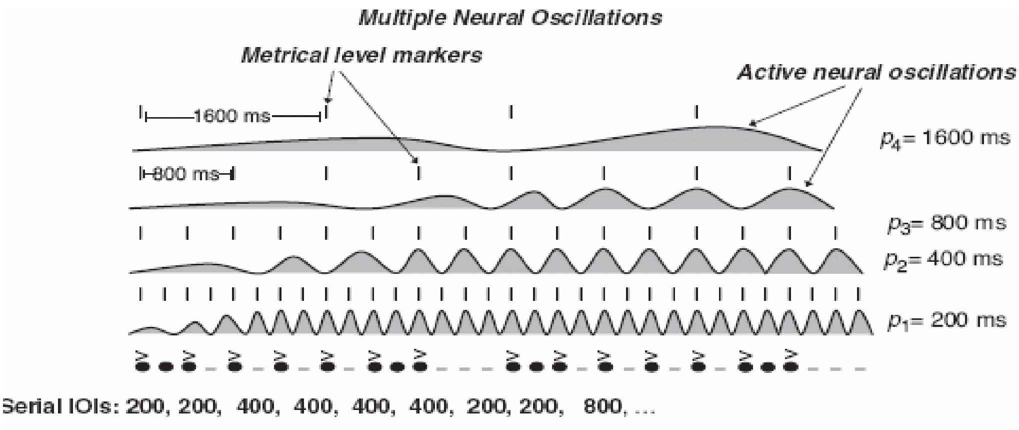

Figure 4. *Illustration of Metric Binding Hypothesis (Jones, 2009).*

CHAPTER 3

METHODOLOGY AND RESULTS

The purpose of this study is to understand how irregularity effects temporal and figural perception of rhythmic structures. In general terms the question covers a large area within the time cognition studies and the music theory. In order to simplify the analytical difficulties, the experimental study focuses on the initial reactions of the participants, which may involve preparation of the processes and procedures used in rhythmic adaptation. For that purpose, short auditory rhythmic samples, consisting of 4 notes, are used in the experiments. 4:4 is a very common rhythm type, and 4 notes considered as a representative minimum unit. Also, WM storage capacities are discussed to be between 3-5 items, so using four notes is useful in terms of analyzing the memory factor involved in rhythm perception (Cowan, 2010). Rhythmic irregularities may correspond to many different complex structures established in the music theory that are impossible to capture in a single study. In that sense, the analysis of rhythmic irregularities in this study is limited with the investigation of how lateness or earliness of an expected note influence the figural representation of the rhythmic pattern, and the temporal judgment of the whole sample and the adjacent intervals. The irregularities are created by changing the position of regular second note by IOI/3 behind or ahead the expected point (Figure 5). So, finding a metric grid requires abstraction of dividing each interval into 3 notes. This requires an advanced rhythmical division used in certain musical genres such as Swing, which is usually used in Jazz music (Liebman, n.d.). Hypothetically it was assumed that participants would not be able figure this division as the information to be gathered in experimental framework is not adequate to make a comprehensive analysis of the metric structure of irregular rhythms.

The question regarding an altered perception of early and late note has been raised in several studies and the common assumption is that in the long run the temporal distance can be computed in the same way, regardless of the temporal position of the oddball (Jones, 2004; Schulze, 1992). Actually Jones predicts a possible asymmetry between early and late expectancy violations due to absence of stimulus in late condition and proposes it as a research question in future studies, which is endeavored to be fulfilled in this study. Another concern related to the experiments is there are two emergent duration contexts: the short intervals constituting the rhythm samples and the whole duration of these samples. The instructions before experiments explicitly refers to whole duration analysis, but possible interaction of the smaller intervals and the whole duration also included in the discussion (Buhusi & Meck, 2009; Moon & Anderson, 2013; van Rijn & Taatgen, 2008). In light of these arguments, this study predicts an asymmetry in short term structures, depending on the position of the oddball stimuli. Nevertheless, this anticipation also includes different profiles for musician and non-musician groups. Possible differences between the groups in their perception and reproduction of the experimental stimuli will be analyzed according to the time perception and memory models discussed above. Although musical training would be expected to produce more efficient solutions to cope with irregularities, such effectiveness should be valid in terms of musical context that possibly contain many other factors such as tone, pitch, timbre etc.. Indeed, experimental studies report an opposite effect (Hébert & Cuddy, 1998; Yee et al., 1994), which might be due to short introduction of test samples and lack of musical context therein.

Experimental analysis includes 2 experiments. The auditory samples used in the experiment are displayed in Figure 5. Experiment 1 is the perception task where the total durations of a standard and comparison rhythms are judged. Experiment 2 is the reproduction task where the same rhythms will be presented in a random order and participants are expected to reproduce them by pressing keyboard keys. Actually, four experiments were planned to be conducted, but due to some complications other two experiments and a part of the Experiment 1 and 2 could not be included in the analysis. Initially experiments was intended to include two duration groups: 2250ms and 1800ms. In Experiment 1, the standard for the shorter duration group was set wrongly and consequently this duration group is removed from analysis. It was also the case for Experiment 2, as this information does not have a test condition anymore. The Experiment 3 included estimation of the total durations of the samples. For this session, one condition of the longer duration group (regular samples) was not recorded. As the remaining part is not comparable with the other tests, this experiment was also cancelled. Experiment 4 was a variation of Povel & Okkerman's (1981) study, which was intended to reveal grouping strategies of the participant groups. However, the expected effects could not observed and this experiment was also cancelled. The missing data, including the shorter duration (1800ms) analysis of Experiment 2 and 3, and also their comparison are included in the Annex A.

Total length: 2250ms

| . . | . . | . . | Regular (IOI [Inter Onset Interval]: 750 ms)

750ms 750ms 750ms

| . | . . . | . . | Irregular (early 2nd beat)

500ms 1000ms 750ms

| . . . | . | . . | Irregular (late 2nd beat)

1000ms 500ms 750ms

Figure 5. *Illustration of the samples used in the experiments. Horizontal lines show the audible beats, dots are silent beats.*

The hypotheses to be evaluated through the empirical data are as follows;

1- Attentional expectancy violations create certain kinds of biases according to the properties of the oddball stimulus, i.e., notes heard after or before the regular beat will change the judgements regarding the whole pattern or the proximal intervals.

2- Perception of rhythmic structures involves both temporal and figural representations. While temporal representations include encoding of real time information, patterns include relative ratios of intervals.

3- Musical training leads to a different approach to rhythm perception that can be tracked in musicians' reactions to expectancy violations as compared to inexperienced music novices.

3.1. Experiment 1

Experiment 1 aims to explore influences of expectancy violations on temporal perception. Specifically, it analyzes whether structural properties of a rhythmic sample influences the final judgment of its temporal duration in comparison of a standard. Quantitative and qualitative differences between groups will be discussed as evidences for effective representation strategies developed in musicians. The task is to compare the total durations of a standard and comparison rhythm and to determine whether the second one is equal to, shorter or longer than the first one. The standard always is an equidistant four note sample with a total duration of 2250ms. The comparison rhythm lasts 2250ms or 1800ms, but the 1800ms conditions are cancelled due to a technical error. The timing of the second note differs between the sample types. It only remains unaltered in the control condition. The manipulation of the second note is assumed to create a violation of the dictated standard meter and affect the final judgment of the participants according to the temporal position of the irregular note. The second interval is altered (or kept the same) with respect to the first interval, while the third interval always remains the same. The purposes of the test include capturing an asymmetry between the early and late oddball stimuli and creating different profiles for the groups according to the related memory and perception paradigms.

3.1.1. Method

Participants

10 musician and 10 non-musician, in total 20 university graduated male participants between the age of 25-45 were invited to the experiment. The members of the musician group are professionals with at least 10 years of experience with their musical instrument. The main instruments played by the participants vary between electro guitar, drums and bass guitar. All are playing similar musical genres and have a regular stage performance schedule. Accordingly, they practice with their instruments at least 10 hours a week. They follow this schedule at least for the preceding 3 months period. The members of the non-musician group scales from zero experience to at most very seldom training with a specific instrument but without any band or live performance. Non-musicians have not been practicing with

an instrument playing music at least for the last 3 months. The levels and degrees of musicianship, participants' general approach to music and participants' opinions in terms of their evaluation of the entertainment level are collected through after experiment survey (Annex B).

Stimuli

The experiment was conducted with a laptop computer in a silent room via Open Sesame 3.1 software. Participants wore Sennheiser HD 205 headphones during the experiment. The tracks were recorded with FL Studio 11 as equitonal, 4 beat samples. There are two duration groups for each sample; (IOI:750ms x 3) 2250ms and (IOI:600ms x 3) 1800ms. Among those, three categories of samples were used; regular, second beat delayed for IOI/3 and second beat ahead for IOI/3ms. The note used in all samples has 330 Hz frequency and lasts 75 ms. The duration of the note is always included in the IOI length. Participants gave their answers via keyboard keys labelled with stickers displaying appropriate figures of the comparison (<=, =, =>), by using their dominant hand. The buttons to be pressed are adjacent keys of 'h', 'j' and 'k' respectively on a 'Q' keyboard.

Procedure

The task is to compare the total duration of standard and comparison rhythms and specify the relation between these two. The comparison could be the regular, the early, or the late second note condition. The comparison tracks followed the standard in each trial in a random order. There were 6 trials for each condition. At the beginning of each trial, participants should press any key to start playing the samples. When samples are played, a fixation dot appears at the center of the screen and also there is a 1 second gap between the standard and comparison so that they can be perceived as separate rhythms. After the presentation of the stimuli, symbols similar to the ones on the keyboard are displayed on the screen (<=, =, =>) and participants should specify whether the total duration of the second rhythm was equal to, shorter or longer than the satndard (Figure 6). Participants received written and verbal instructions before the experiment started and a practice block of 6 trials (comprising 1 set of all combinations) at the beginning of the test.

Actually the correct answer was always equal because even if the second note came too early or was delayed, the third beat occurred at its designated time. In other words, although there were 3 different combinations for 2250ms long comparison patterns, namely 'standard vs. regular', 'standard vs. early 2nd note' and 'standard vs. late 2nd note' the correct answer is always "equal". Due to some misconception, the standard for the 1800ms was also the "long" standard (2250ms) and not the "short" standard (1800ms). Because of this mistake, the short conditions were cancelled. The standard sequence is always an equidistant rhythm with 750ms IOI that lasts 2250ms in total. The Experiment 1 took approximately 6 minutes to complete.

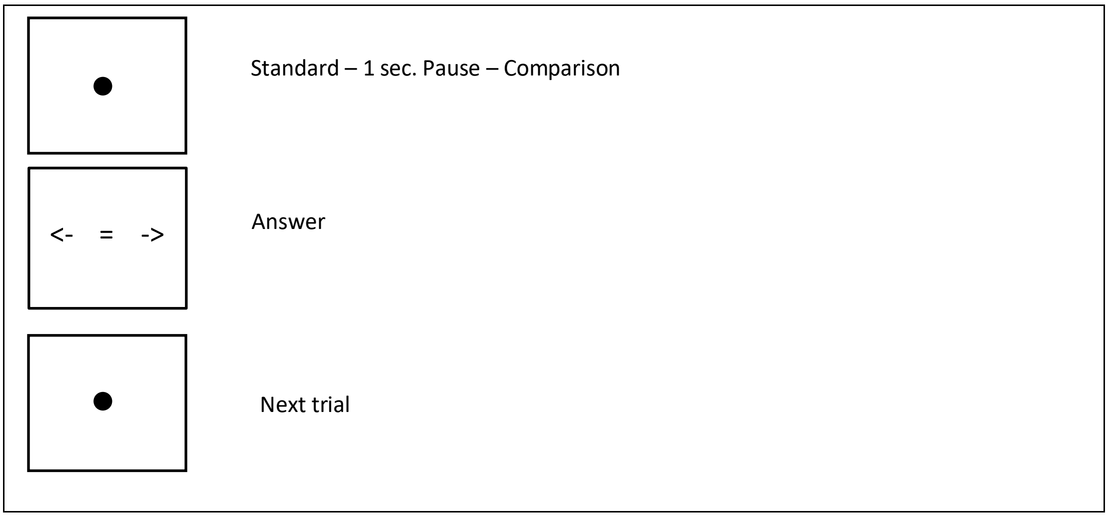

Figure 6. *Experiment starts with a keypress then a fixation dot appears. The standard and the comparison play with 1 second delay in between. The response keypress visualized on the screen with shapes corresponding to the labelled keys. After the response, the next trial begins.*

3.1.2. Results

Response times of all trials were transformed to z-scores in order to track outliers. Trials with extreme values exceeding approximately 8 seconds were removed, as they are believed to occur due to external distraction. The remaining data was subjected to a statistical analysis. Helmert contrasts are used for the three comparison levels “regular”, “early 2^{nd} note” and “late 2^{nd} note”. In the first Helmert analysis the regular rhythm is contrasted with both irregular rhythms, while in the second Helmert analysis the early and late rhythms are contrasted.

A 2x3 mixed measures ANOVA was used to analyze effects of musicianship as a between subjects factor among sample types (regular, early 2^{nd} note, late 2^{nd} note). In this analysis, only the correct answers taken into consideration. The results indicated that there is a significant effect of sample type on correct answers for both groups (F $(2,35)=29.583$, $p<.001$, $\eta_p^2=.622$). However, there were no significant differences between the groups. This outcome is valid for the comparison of regular vs. irregular (F $(1,18)=56.506$, $p<.001$, $\eta_p^2=.759$) and also within the irregulars between the late vs. early second note samples (F $(1,18)= 4.743$, $p<.05$, $\eta_p^2=.209$). While regular samples are answered correctly for both groups as equal to the standard, the duration of early samples perceived more accurately, compared to late samples. Descriptive statistics of this analysis are given in Figure 7.

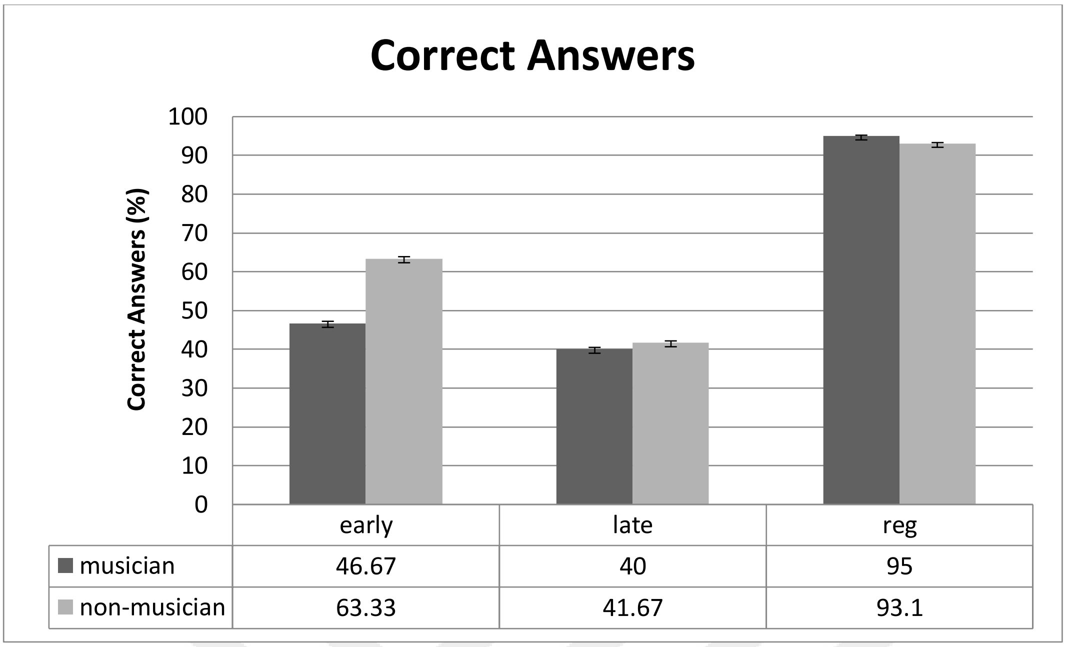

Figure 7. *Interaction plot and descriptive statistics of the mean correct answers given for the three rhythm types by musicians and non-musicians. The data indicates that the distribution of correct answers is highest in regular samples, as compared to irregular samples. Among irregular samples, early note samples are perceived as more correct compared to late note samples. [Error bars represent SE].*

Also a three-way ANOVA was performed over the entire data obtained from Experiment 1, additionally including the type of answer (shorter, same, longer) as a within subjects variable. Firstly, there was a significant effect of sample type between groups (F (2,25)=5.754, p<.02, η_p^2=.242). According to the Helmert contrast analysis the mentioned effect is notable for regular and irregular samples (F (1,18)=6.688, p<.02, η_p^2=.271), and also within the irregular samples (F (1,18)=5.754, p<.04, η_p^2=.217). Musicians were slightly better at matching the temporal duration of regular samples (Figure 8). On the other hand, concerning the irregular rhythms, non-musicians perceived the total duration of the samples more accurately compared to the musician group (Figures 9 and 10). Furthermore, musicians observed to have a tendency towards perceiving the irregular samples as longer, while non-musicians display a balanced distribution: shorter perception of early samples, longer perception of late samples. The second significant effect is visible among replies given to each sample for both groups (F (4,64)=19.525, p<.001, η_p^2=.520). Without any group effects, firstly, this effect includes that correct answers between regular and irregular rhythms are significantly different than ‘shorter’ and ‘longer’ answers (F (1,18)=58.145, p<.001, η_p^2=.817). This indicates that regular rhythms, with respect to the other variables, were perceived better and answered correctly by all participants. Secondly ‘shorter’ and ‘longer’ answers given to irregular samples are significantly different for both groups (F (1,18)=6.847, p<.02, η_p^2=.276). So, the advantage of early over late samples remains effective for all participants.

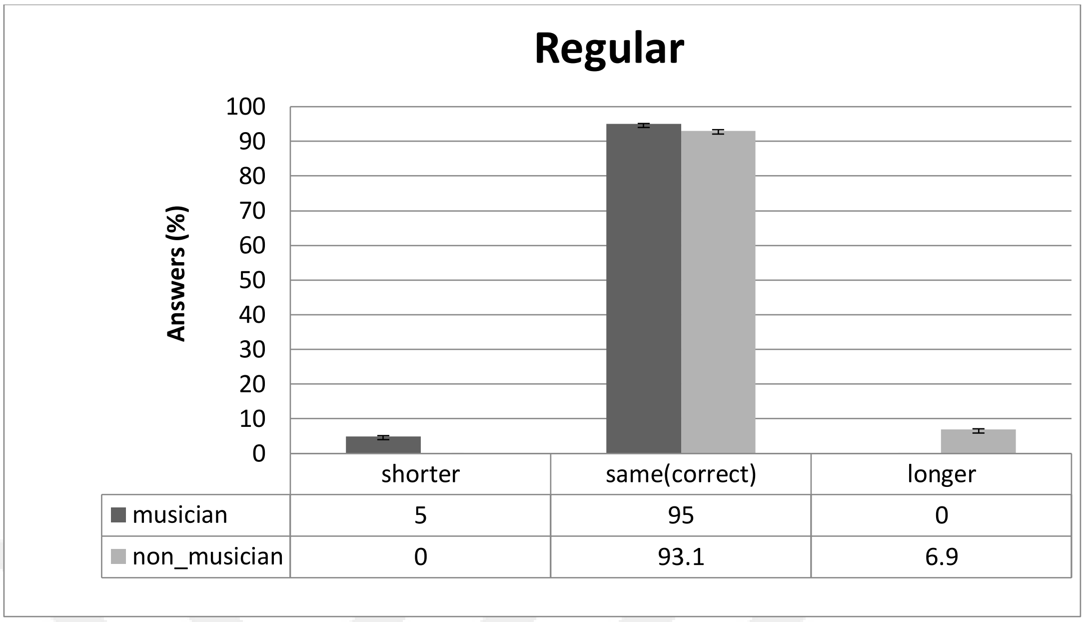

Figure 8. *Interaction plot and descriptive statistics of the percentage of given answers for regular samples by musicians and non-musicians [Error bars represent SE].*

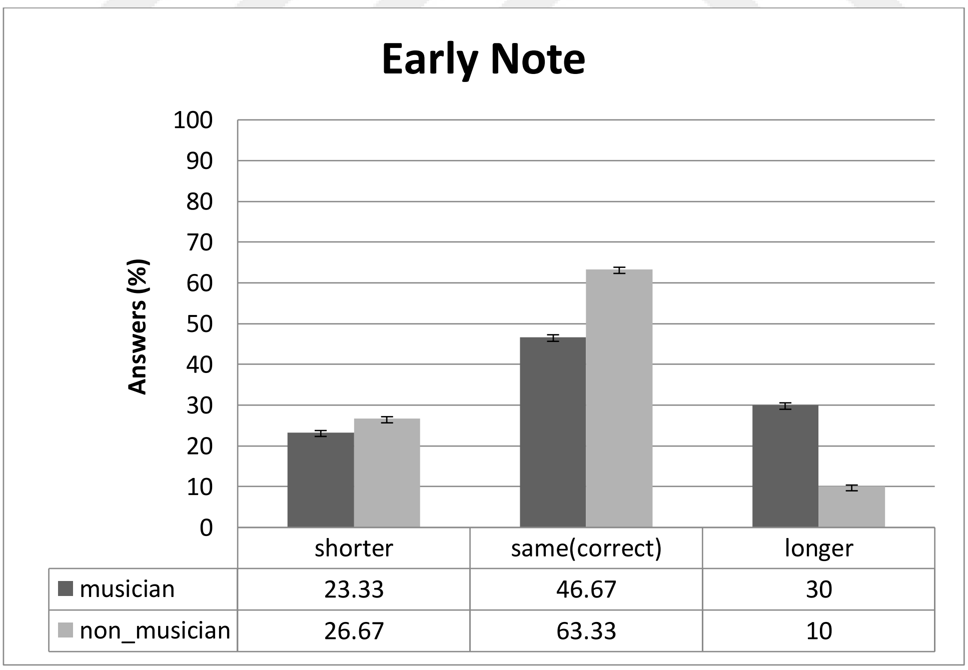

Figure 9. *Interaction plot and descriptive statistics of the percentage of given answers for early second beat samples by musicians and non-musicians. [Error bars represent SE].*

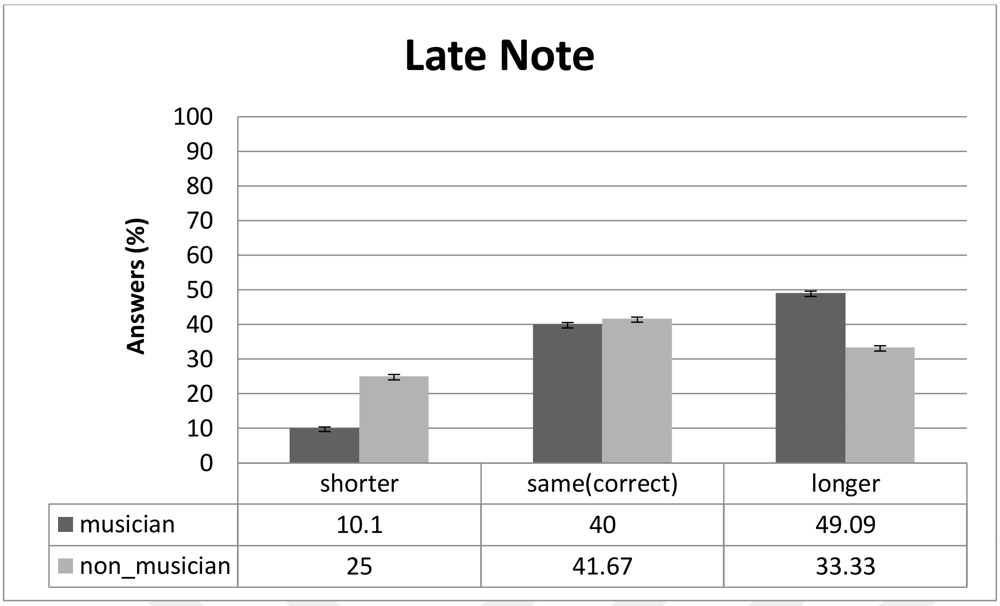

Figure 10. *Interaction plot and descriptive statistics of the percentage of given answers for late second beat samples by musicians and non-musicians. [Error bars represent SE].*

3.1.3. Discussion

The overall analysis of Experiment 1 indicates that all participants were able to match the regular rhythms with the standard correctly in most instances. The irregular samples were perceived less accurately. Comparison of the irregular patterns among each other shows that the early note samples were matched with the standard better, while the late note samples had a tendency to be perceived as longer –slightly for musicians, more pronounced in non-musicians (Figure 9 and 10). In the frame of the experimental setup, the oddball stimulus is introduced as early as the second note of the rhythm. While this manipulation is intended to explore the effect of temporal position on temporal judgements, it also provides evidence in terms of a possible primacy effect (Treisman, 1964). The findings of the study suggest an advantage of early oddball stimulus over late, especially for non-musicians. This probably occurs due to short nature of the samples, so does not necessarily contradict with the idea that they could be computed the same way in the long run. In this regard, one possible explanation can be, in the late note samples, as shorter interval comes second, it creates less time to process the irregularity occurred in the first interval, when the judgement is made in comparison to an explicit standard interval (Terry et al., 2016). (In the referent paper this indication is discussed as a global effect depending on violation of the expected beat, not on a local context such as the preceding interval. In the present study, since the standard explicitly sets a metrical grid, the mentioned local effect could be accepted as similar to the nature of a possible global effect, since the mentioned beat structure is also assumed to be an expectancy profile). Regarding this limited processing time argument, Povel and Okkerman (1981) argues a threshold for processing the acoustic properties of the auditory stimulus between 150-250ms. The shortest interval used in this experiment is 500ms, which is the double of the maximum threshold. However, the difference between the expected note and the irregular note is 250ms. If we accept that the intervals of the regular sample could be represented properly, it is possible that simulation of the standard -and the expected note- also needs a proper processing time and the irregular note disrupts this process (Barsalou, 2008). Nevertheless, this argument would still not be explanatory concerning the asymmetry between the late and early oddball. Another possible explanation within the limits of the study is, early introduction of the stimulus resets the system and assigns a new expectancy point, while late introduction drives the system into an ambivalent state for a brief period, as the lateness also signifies absence –termination (Jones, 2004). In this experiment, the number of notes is known beforehand, so the late oddball does not signal termination explicitly; but as the referent note is missing, it could still alter the final judgement as an automatic process. In that sense, it is possible that in those cases, where a judgement cannot be formed, the perceived lateness due to an additional estimation space might influence the final decision towards the temporal position of the stimulus more, compared to the early oddball.

Regular Trials

Regular comparison samples were identified as correct almost entirely by both groups. As can be seen in Figure 9, there are only very few wrong answers given for the regular trials. Since the standard and comparison are identical in those trials, this was an expected outcome.

Early Note Trails

The analysis for the irregular samples provides insight into the previously mentioned early and late oddball contrast that allows a comparison between the participant groups. When we look at the distribution of responses for early note samples (Figure 9), both groups gave correct answers more than the other options. However, musicians' success rate is lower than that of non-musicians. Also, in relative terms, they answered more often 'longer' than 'shorter' compared to non-musicians. Such poor performance of skilled participants against irregular structures argued in the literature to be due to searching for a referent beat or similar structural features in order to provide a coherent representation, as a consequence of their training (Hébert & Cuddy, 1998; Yee et al., 1994). Thus, the general tendency of the musicians to perceive the early note samples as 'longer' can be associated with their tendency to produce a healthy representation of the rhythmic pattern in the long term, which is a necessity for musical performance. Accordingly, it can be proposed that they might be adding an extra time to the perceived duration to estimate the gap and find a minimum grid to fit the metric structure. As the patterns are short, this effect might be more visible in this study.

On the other hand, while non-musicians selected the correct option more than the other options, they also perceived the early note samples as 'shorter' more than 'longer'. This advantage of 'shorter' answers to early note samples might indicate that the primer stimulus –the first interval- was effective in their final judgements. Baddeley (2012) argues that in retaining serial order the primer item is given more activation rate and this value decreases gradually for the following stimulus. This primacy effect also discussed concerning its neural correlates in selective attention

(Treisman, 1964) and repetition attenuation (Barron et al., 2016) theories. It can be interpreted that the primer introduction of the short interval, as it gains more activation, had more strength in the final decision. Also the problem state buffer discussed in Borst et al.'s (2010) paper is defined as a one chunk buffer that is only needed if an intermediate representation is required. In that respect, the task in this experiment is to compare the durations of two rhythmic samples. In some of the trials, it is possible that the introduction of the short interval disrupted the standard duration –which is a different temporal context that shares the same buffer- and become the only available information for making a judgment. This later indication is more visible in non-musicians as their wrong answers are mostly 'shorter' option, but it can be argued that it was the case in some trials of musicians as well. Moreover, this indication entails existence of two temporal contexts; the intervals that constitute the sample and the total duration of the sample. Possible interactions between these two will be elaborated in the following sections of the study.

Late Note Trials

The distribution of answers given to late note samples provides a different picture. Musicians chose 'longer' option more than the other two choices. In comparison to early note samples, the rate of the 'same' answers relatively stays the same, while a considerable amount of 'shorter' answers are transferred to 'longer' option. For non-musicians, although the correct option was selected more than other choices, it seems that some part of 'same' answers are transferred to 'longer' option, while the 'shorter' answers relatively stays the same.

In terms of musicians' answers, it is still arguable that irregularity impairs their judgement in the short term. Moreover, as the rate of the correct answers stays the same, it can be defended that the position of the oddball does not affect them in a qualitative way i.e. their strategy does not differ with the structural variety of the irregularity. The transfer between the 'shorter' and 'longer' answers can be interpreted in three ways. Firstly, musicians probably tried to find a metric compound by adding an extra time to the perceived duration. Secondly, they were influenced by the discussed primacy effect in some trials, presumably when the first interval disrupted the representation of the standard. Thirdly, the increase in choosing the 'longer' option in late note samples might also be related with a cognitive state, occurring due to the absence of the stimulus. Although this implication is rather speculative, in Dynamical Systems Theory of cognition it is argued that chaotic states, which are prone to be settled in emergent features, occur when an attractor state cannot be defined properly (van Gelder, 1998). In that sense, this alternative option is suggested as a possible boost effect on the first interpretation i.e. if the representation of the standard is distracted, the mentioned added span for a metric structure time contributed to longer perception.

Non-musicians' accuracy rate drops drastically in the late note samples. It can be said that within this group, temporal position of the oddball stimulus shows an asymmetry and qualitatively change their judgments. It can be argued that their decisions were impaired as to make more of randomly balanced choices, while the main effects of the previous analysis are still visible –the ratio of the 'same' answers is more than other two options and the 'longer' answers are slightly more than the ‘shorter’ answers, due to a possible primacy effect. While this is relatable with the drop in the rate of correct answers between early and late note samples, relatively balanced distribution of the ‘shorter’ and ‘longer’ options in the late note samples requires further explanation. In comparison to musicians, if we accept that they are not bound by an additional operation in search for a metric compound, it is arguable that the ‘shorter’ option is also within the scope of the cluster of attractor states (van Gelder, 1998). In that context, the drop in the rate of correct answers can be used as a supportive inclination, which predicts that non-musicians’ representations are unstable in the late note samples. Consequently, it can be argued that absence of the stimulus, since the standard dictates a metric bound, disrupted the non-musicians more, should they lost concentration. Nevertheless, it should be noted that the current data set and the scope of the experiment do not provide a reliable framework for discussion of state definitions made in Dynamical Systems Theory of cognition. They are rather proposed as possible explanations to be addressed in future studies.

The experimental setup presents the standard and the comparison with a 1 second delay that the standard has a recent element that would be expected to be recalled properly (Salvucci & Taatgen, 2008). This recall can be argued to be a simulation of the event structure and would be expected to reflect the real-time properties of the rhythms, since the events are limited with four items (Barsalou, 2008). Such simulation of the rhythmic structures argued elsewhere as a general strategy in rhythmic adaptation and observed to display common properties with Baddeley’s (2012) phonological loop such as the mentioned articulatory suppression effect (Berz, 1995; Pich, 2000). As a general remark on the poor perception of irregular rhythm trials, it can be assumed that the proposed expectancy violation disrupts the simulation or articulation of the standard and altered the perceived duration. While the phonological loop –or the musical loop extension (Berz, 1995)- keeps a representation of the standard in a subvocal pattern, the problem state buffer (revised version of episodic buffer by J. Borst et al. (2014)) holds the whole duration to be compared with the new target duration. In that sense, in some of the trials the attentional focus might be distracted or concentrated specifically on the nature of the irregularity that alters the content of problem buffer and cause impaired judgments. The details of this process can still be elaborated with above arguments concerning the sample types and participant groups. Nevertheless, possibility of such an indication provides a foundation for discussing the effects of musical training on utilization of mentioned WM units and contained procedures.

3.2. Experiment 2

The second experiment includes the reproduction task. Participants should exactly reproduce the patterns they hear. This test block is expected to reveal the hypothetical effects between the participant groups and also the effects of irregular rhythms, in between and within subjects conditions, without an external standard. Also, the outcomes of this study will potentially provide a detailed account of the discussions made in Experiment 1, concerning the argued strategical differences between musician and non-musician groups.

As mentioned at the introduction of this chapter, there were actually two sample length conditions in this experiment: 2250ms and 1800ms. Since the data concerning the 1800ms condition was partially missing in the other two experiments, the 1800ms condition was also removed from the analysis of this experiment. It should be noted that both groups displayed a convergence effect between the duration groups, i.e. overestimated the shortest duration (1800ms) and underestimated the longer duration (2250ms) as predicted by Vierdort's Law (Lejeune & Wearden, 2009). However, it has no qualitative effects on the significance of the results reported here. In that sense, if this experiment were to be conducted only with 2250ms samples, the reproduced total durations, and accordingly the interval estimations would be expected to be slightly higher than the reported durations. The details of the 1800ms conditions and its interactions with the 2250ms condition can be found at Annex A.

Experiment 2 contains two independent variables: sample type (regular, early note and late note) and interval (first, second and third) (Figure 5). They will be analyzed according to the normalized values of each interval and the total duration estimations of whole samples. Also the divergence of each interval from the expectancy point is displayed in Figure 13. These values are gathered by dividing the reproduced interval durations by the relative ratio of that interval within the total reproduced duration in each trial. In that case, estimations for the first and second interval of early and late samples are divided by 'total time*2/9'. The second and first intervals are divided by 'total time*4/9' and for all regular IOI intervals 'total time*3/9'. Since the irregular notes metrically require division of the regular interval into three, the total interval count in a coherent meter would be nine, and the divergence ratios are calculated upon that division.

3.2.1. Method

Participants

The participants of Experiment 1 also attended Experiment 2.

Stimuli

The equipment and samples of Experiment 1 are used. Participants are required to exactly reproduce the target sample by pressing the 'click' button four times. They use their dominant hand. The 'v' button is labelled as 'click' button on the Q keyboard.

Procedure

Participants are informed about the instructions before the test and received 6 practice trials (1 trial for each condition) to get accustomed to the task. They are explicitly asked to be faithful to the timing between the notes. Before each trial participants should press any key on the keyboard to start listening to the samples. While the track is playing, a fixation dot appears at the center of the screen. Subjects are requested to start reproducing the track after the sample played by pressing the 'click' button. They should press the 'click' button four times to reproduce the target pattern exactly. Afterwards, they need to press any key again to start over with a new trial. Samples are presented in a random order and there were 6 trials for each condition.

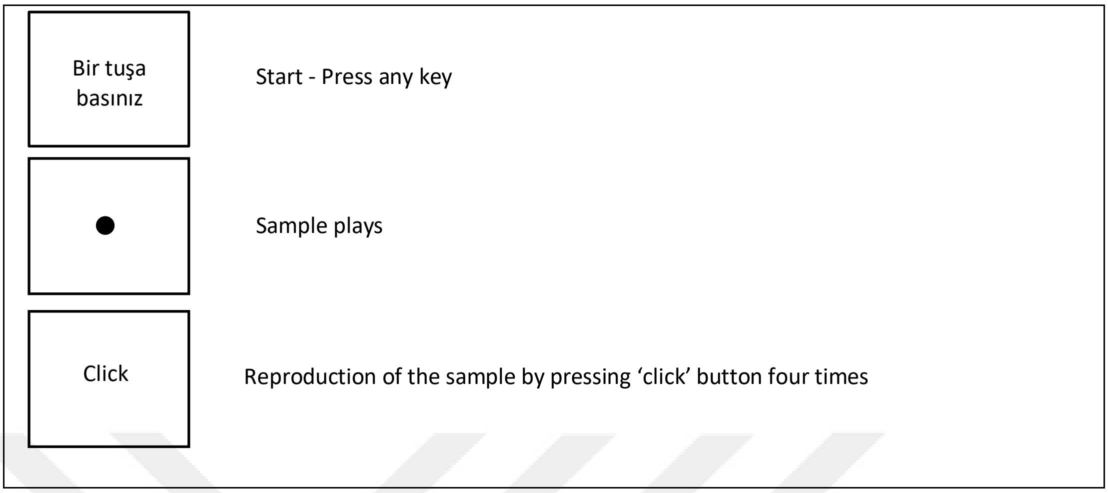

Figure 11. *Experiment 2 starts with a key press. Then a fixation dot appears on the screen while the test sample plays. The 'click' phrase is displayed on the screen, when the answer should be given. After the sample plays, participant must press any button to start the next trial.*

3.2.2 Results

A 3x3 ANOVA was used between groups (musician, non-musician) with independent variables containing the response times for each interval (first, second, third) and sample type (early 2nd note, late 2nd note regular). The intervals are matched according to their actual sequence, so for the irregular samples the shortest and longest intervals were compared to each other. When all the variables are combined a significant between groups effect was observed (F (2,36)=7.588, p<.05, η_p^2=.297). Descriptive statistics of interval estimations analysis are provided in Figure 12.

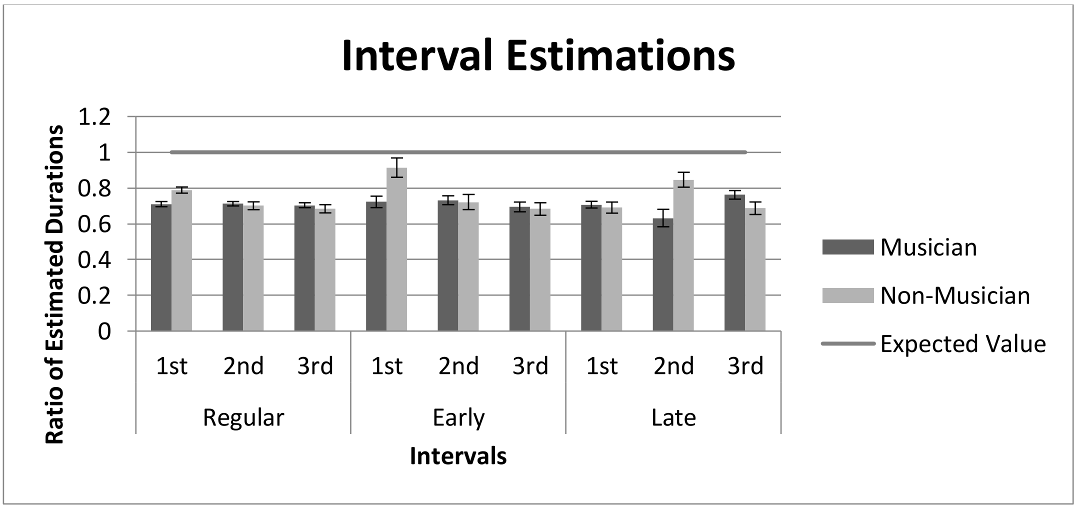

Figure 12. *Estimated durations for each interval. [Error bars represent SE].*

Additionally, the calculated ratios for irregular sample intervals are analyzed for each group separately. The reason for conducting this analysis is to observe in details whether estimation of intervals between the late and early samples change significantly for each group. This analysis compares the shortest and longest intervals respectively. So, the first interval of the early note samples (500ms) is matched with the second interval of late note samples (500ms) and similarly the longest intervals (1000ms) were compared to each other, while the analysis of the last intervals (750ms) stays the same. For musician group the ANOVA analysis yields a significant difference between the early and late note samples, (F (2,14)=4.531, p<.05, η_p^2=.335). For non-musicians, the analysis between the intervals of irregular samples is insignificant, thus not significantly different from each other, (F (2,14)=.354, p<.6, η_p^2=.038). Therefore, data indicates that in respective matching of the intervals, non-musicians reproduced more or less the same intervals in both late and early samples, while musicians reproduced different intervals for these samples (Figure 12).

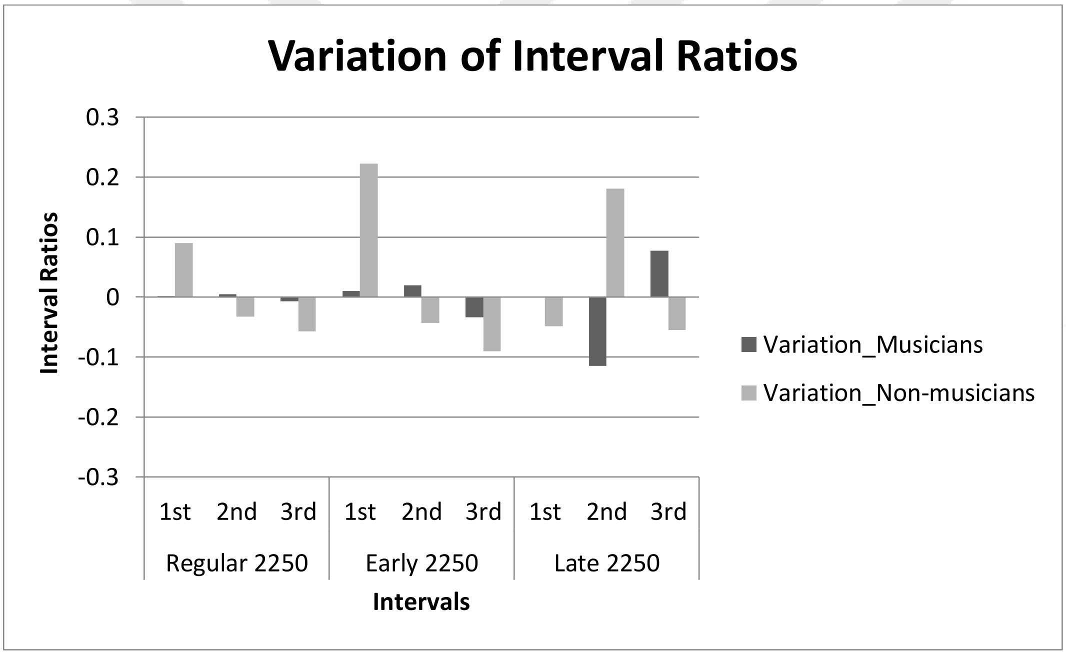

Figure 13. *Variation of the interval ratios for both groups with respect to expected ratios of the estimations. 0 represents the expected ratio.*

Sum of all three intervals produced in Experiment 2 shows no significant group or sample type effect, (F (2,29)=.301, p<.6, η_p^2=.016). Figure 14 displays the descriptive statistics of total duration estimations.

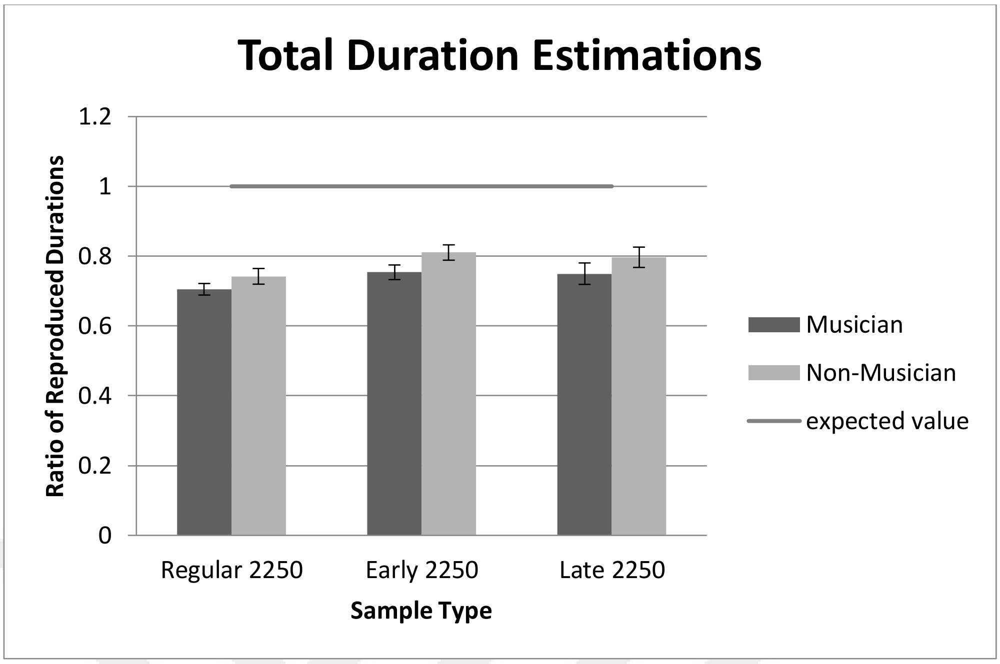

Figure 14. *Ratio analysis of total duration estimations in Experiment 2. [Error bars represent SE].*

3.2.3. Discussion

When all variables of the test are put together, the statistical data yields a significant difference between the groups. This result contains a 3 way interaction ANOVA between sample types (regular, early and late) and the produced intervals of the samples (1st, 2nd and 3rd). In that respect, as the sample type changes, the produced interval lengths also change between groups. However the reproduced total durations do not change between sample types. This finding is in conflict with the outcomes of the Experiment 1, as there was an asymmetry between groups, and also between the temporal judgments regarding the sample types. These contradicting findings limit the findings of the Experiment 1 to conditions where the standard is set explicitly. When the rhythms are presented individually estimated durations do not change, hence both groups were able to estimate a unique duration for all sample types (Figure 14).

The reproduction of regular samples is quite successful for musicians and non-musicians, since they can reproduce a balanced distribution of the intervals. Lower estimations for both groups (Figure 12) can be explained by the additional cognitive loads of paying attention to each note and reproducing them, as predicted by prospective duration judgment paradigm (Zakay & Block, 2004). However, there is a certain difference in the figural representation of the regular samples between the groups. Non-musicians' duration estimations show a gradual decrease at each succeeding interval. Repetition suppression theory explains such gradual decrease towards repeating stimulus as a neurobiological phenomenon (Barron et al., 2016). Repetition suppression has been reported in separate EEG, BOLD and fMRI studies and is considered to be a factor oriented in increased efficiency of representation (D. M. Eagleman & Pariyadath, 2009). On the contrary, musicians reproduced a flat profile for the intervals for the regular samples that the ratios of each interval are equivalent. Practically, their resistance to repetition suppression can be related with musical training, as production of unequal intervals might create poor performance in terms of musical skills. Theoretically, the explanation concerning these balanced intervals would be expected to be competent at the neural level. Entrainment is claimed to be neural level adaptation, comprised as the attentional energy is narrowed and a clear expectancy profile is established that the peak points of external events (position of notes) coincide with the peak points of neural oscillations in synchrony (Jones, 2009). Moreover, Barnes & Jones (2000) found evidence that intervals that follow harmonics of the minimum grid of a rhythmic structure (divisions such as, IOI: 200ms, 400ms, 800ms etc.) are detected more easily than different context IOIs. In that sense, the regular rhythm has equal intervals that can be detected easily. The important point is musicians seem to be quite fast in adapting to an ongoing rhythm with strong meter. It can be deduced form the data and the related literature (Barnes & Jones, 2000; Jones, 2009) that this adaptation can be related with instant stabilization of neural energy due to musical training. Moreover, such an outcome can be explanatory as to why the groups showed different profiles in Experiment 1; non-musicians has a wider focus which is more prone to be interrupted by disruptors and show different profiles according to the quality of the stimuli (such as earliness and lateness). On the other hand, musicians has a more stable approach to event structure that may alter the nature of mistakes, but do not affect the qualitative aspect of strategies (the constant ratio of correct answers to irregular samples in Experiment 1).

Reproduction of the irregular samples shows certain differences between groups (Figure 12). One thing to notice is increased reproduction of the shortest interval (500ms) in both irregular samples by non-musicians. Vierdort's Law (Lejeune & Wearden, 2009) predicts that within a sequence of short and long intervals, the shortest intervals are overestimated and longest intervals are underestimated to a point of convergence where an indifference interval is represented. Taatgen and van Rijn (2011) provide an explanation of such convergence of interval representations through their memory model, where past intervals affect the judgment of a recently presented interval. This latter model offers a memory pool of intervals where the experienced durations influence each other, recent elements has more strength compared to past experiences and within the limits of the model all stored items are open to contamination by other items. Intervals reproduced by non-musicians shows contamination effects between the short and long intervals. However, these intervals are observed to be solid duration representations that their allocated temporal spans do not change between different orderings –at least the third interval would be expected to alter as the most recent items are longer or shorter than this duration in early and late note samples respectively. In that sense, the observed convergence effect might be related with the encoding of the intervals rather than a memory property. From this perspective the boosted increase of the shortest interval in figural terms can be related with suppression effects such as the 'proliferation effect' by David M. Eagleman (2010) that argues the briefer stimulus appears to last longer. Nevertheless, it is beyond the scope of this study to test if the proliferation effect is also applicable to interval timing. This boost in the shortest interval is relative to its ratio within the whole sample (Figure 13) and in absolute terms it is closer to the actual duration (Figure 12). It can be tested in a separate study to see if the shortest interval is represented better and consequently closer to the actual duration, or it is a perception illusion that boosts the perception of this interval.

Musicians were observed to produce significantly different intervals between the irregular samples. They present a flat profile for the early note samples again (Figure 12). If we follow the above argument it can be said that musicians seem to be more effective in figural encoding compared to non-musicians. Several studies argue that adaptation to a rhythmic structure requires detection of the smallest grid (Hébert & Cuddy, 1998; Povel & Essens, 1985; Yee et al., 1994). Once the minimum unit can be represented, intervals that are harmonic iterations of this minimum grid can be represented automatically, as long as they are metrically bound (Jones, 2009). In the present experiment the irregular note requires a division of each interval into three parts, which in musical terms refers to playing a 4:4 rhythm with 8^{th} note triplets. In the experiment, each of these 8^{th} note divisions covers a 250ms span. Although this metric structure is not explicitly presented through the experiment, since the musician participants are known to practice such patterns in their area of musical expertise, it is possible for them to somehow understand the fractional relation between the intervals. It is arguable that they were able to match the metric division required to make sense of the rhythms in connection with their past experience with such patterns. This outcome is also arguable in terms of pacemaker-accumulator models of interval timing (Wearden, 2008). Accordingly, the difference between the heard sample and the pulses counted by the accumulator could be detected and necessary addition and distraction calculations might be applied routinely to first and second intervals, which results in a balanced distribution of the intervals. However, the musicians could not keep this balanced representation in the late note samples. This has certain outcomes in consideration of mentioned entrainment and pace-maker accumulator theories. Firstly, it should be noted that for musicians the ordering of short and long intervals observed to create different effects. In terms of clock-counter models it is not an expected outcome because the steady nature of the emitted pulses does not predict an asymmetry in different orderings of the same intervals. Furthermore, since the time perception depend on the sum of counted pulses in these models, even if the ordering of the intervals create an altered perception, it should be resulted in different temporal estimations as the count would be expected to be different due to the predicted distraction in the late note samples. As mentioned above the total durations estimated for each sample type was equivalent. Regarding this, a dynamical perspective on adaptation to event structure is more favorable, since it possesses a theoretical potential for explaining occurrence of such asymmetry. One addition to this argument can be that the total time of the samples could be temporal limiting factor for rhythm reproduction. In scope the present study, the asymmetry is believed to be occurring due to ordering of the intervals and musicians' tendency to find metric bound i.e. early notes violate the metrically expected point and assigns a new expectancy profile, while late note creates an additional distraction as the expected point is absent.

Another thing to notice in musicians' reproduction of the late note samples is the increased third interval relative to other sample types. This regular interval (750ms) indeed is the most encountered interval throughout the experiment and considering the discussion of non-musicians estimations, it would be expected to be represented more robustly. However, it is not the case. One argument to be raised in this consideration is that they still have a representation of the total duration and compensated the lost time at the last interval in order to fit with this representation. Equivalence of total durations for each sample type supports this indication. In the discussion of Experiment 1, it was noted that the total duration might be represented in a mechanism such as episodic buffer and it supervises the outcomes of a possible phonological/musical loop (A. Baddeley, 2012; Berz, 1995). Since Experiment 2 does not include an explicit standard, it can be said that the total duration is not distracted by the local changes of events and put a temporal limitation on figural representation. This supervision can be performed in the form of an executive unit or a simple comparator unit as mentioned in the study of J. Borst et al. (2014). The important aspect in terms of this study is that two different context durations (whole duration and its constituting intervals) can be represented simultaneously. Furthermore, Jones (2009) indicates that figural representations are inherently temporal in the form of a fluctuating attentional pulse and temporal data is not needed to be encoded separately. It is relatable that when a pattern is represented correctly, it should be flexible to apply to any temporal context, since the ratios between the intervals would not alter. One addition to this metrical binding theory is that the attentional pulse might be limited by certain factors such as the total duration. It could be a necessary limitation if the assumed flexibility does not cover the inharmonic durations. Hence, perceived duration should be preserved to provide continuum of the attentional focus against distracting out of context durations. Alternatively, it can be a limitation on the metric unit –such as 4 notes in a 4:4 meter- in order to provide local adaptations that may reduce the complexity and increase efficiency of global adaptation.

One last thing is the nature of the total durations between the groups. For musicians it could be related to a parallel processing mechanism with an interactive component between them to limit the representation in a minimum unit. On the other hand, since non-musicians provided indifference intervals, their reproduced total durations are inherently equivalent. This explanation fits with the predictions of clock-counter models (Zakay & Block, 1995). Speculatively it is assumed that clock-counter and entrainment mechanisms could be existing together but applied in different situations. In that respect, while a clock-counter is a default procedure for absolute time perception, entrainment occurs when the expectancy profile is clear and the steady pulses of the clock unit are transformed into analogues dynamical pulses, which create synchrony. Of course the scope of this study is very limited to support such distinct representation mechanisms for different phenomena. In search of such a model, switching between the two perceptual frameworks could be targeted as a research question and possible effects of musical training on efficient utilization of both mechanisms could be investigated.

CHAPTER 4

GENERAL DISCUSSION

The irregularities tested in the experiments yielded significant differences regarding the temporal and figural perception of the rhythmic samples and also these differences displayed different profiles for musician and non-musician groups. The Experiment 1 was concerned with the perception of the whole duration of the samples in comparison to the standard regular rhythm. The standard is deemed to be acting as a metric basis and in that respect the early and late notes were considered as expectancy violations. In Experiment 2, the samples were introduced individually and the total estimation of the duration was not the primary task in terms of the given instructions before the test. Nevertheless, the reproduced total durations supported existence of temporal representations for both groups, while interval analysis provided a detailed account of perceptual differences. These effects are discussed according to the STM models, timing mechanisms and rhythm perception theories presented in Chapter 2.

4.1. Rhythmic Irregularities

Rhythmic irregularities occur on weak meter patterns, where the frequency of the overlap of the strong events (accented notes) and the expected beats based on the starting notes of the repeating cycles diminishes, hence the pattern becomes more complex (Povel & Essens, 1985). On the other hand, the nature of the irregularity may be originated in various arrangements of the rhythmic structure depending on the musical context. The existing literature on cognitive science concerning the influences of these irregularities on temporal and figural encoding covers research on compact or expected ending of rhythmic cycles (Grube & Griffiths, 2009; Povel & Essens, 1985; Yee et al., 1994), ratio analysis of within and between group intervals (Barnes & Jones, 2000; Hébert & Cuddy, 1998) and complex figural relationships such as syncopation and polyrhythms (Fitch & Rosenfeld, 2007; Handel & Oshinsky, 1981). The general outcome of the mentioned studies supports the conclusion that irregular rhythms are more compelling and influence the duration judgments of the presented rhythm. However, among them, Handel (1998) defends that temporal encoding is not effective on rhythm perception, rather gestalt properties emerging according to pattern structures are decisive in the final judgements. Accordingly, while note groups are encoded as patterns, the durations between the groups are not encoded temporally. Hébert and Cuddy (1998) challenges this proposition in two grounds, firstly Handel's (1981) experiments did not give feedback after trials and secondly the between groups durations were too small to process the temporal information. Eventually, the latter study defends the existence of two different encoding mechanism; a context dependent pattern detection unit and a context free absolute timing mechanism. The present study provides and insight to this argument. Using a single standard in a way acts as a feedback concerning the total duration to be compared. In that sense it further exposes the influences of the manipulated irregularities on temporal judgements with reduced noise. Additionally, the small size of the samples also creates a testing environment for detecting whether the source of temporal and/or figural representation is related with the nature of memory storage or encoding strategy.

4.2. Storage of the Temporal Information

The memory models for temporal information –also for other kinds of stimulus features- can be categorized in two groups: multiple-source bottleneck models (A. Baddeley, 2012) and memory pool models (Taatgen & van Rijn, 2011). The former may include a central executive function that supervises the attentional allocation between the units, or may include a comparator unit that conducts routine arithmetic operations to produce a final judgement (Salvucci & Taatgen, 2008). On the other hand, the pool models proposes a unsupervised storage procedure that depends on the interactions between the memory items, in terms of the activation strengths of those items based on certain criteria such as recency, requirements of the current state and other contextual factors (Moon & Anderson, 2013; Taatgen & van Rijn, 2011). In terms of rhythm perception, the role of memory procedures can be discussed concerning storage of patterns and intervals.

Extension of Baddeley's model, in order to fit with observed autonomous characteristics of music cognition, led to addition of a musical loop that shares the functional properties of the phonological loop, but is a specialized unit restricted with musical context (Berz, 1995). Existence of this unit is further tested and the related findings support that the way data is encoded in musical loop is similar to articulation of phonological information, in form of subvocal rehearsal or rhythmic tapping (Pich, 2000). Such representation of a rhythmic structure would be expected to be oriented in preserving the figural characteristics of the target rhythm as the respective ratios of the intervals are all there is to be making sense of a rhythm. Rhythmic patterns inherently possess temporal data. However, if precise estimation of duration is needed to be represented, as it was the case in the current experimental study, another unit would be required to work in parallel to limit this articulation temporally. The existence of such a temporal representation of the total duration is supported by the similar reproduction of the total durations for different sample types in Experiment 3 (Figure 14).The literature provides a background for such arrangements as to what percentage of the attention will be directed towards the stimulus can be controlled by specific instructions (Macar, Grondin, & Casini, 1994). Neurobiological data also supports existence of different structures for metric and figural perception of rhythmic structures (Thaut, Trimarchi, & Parsons, 2014). Nevertheless, it is uncertain whether such an allocation is carried out by a central executive mechanism or is an outcome of the nature of the storage unit.

J. Borst et al. (2014) provide a foundation for multiple tasking in Working Memory. The discussed model introduces a problem state buffer, which possible included in every single unit that process distinct information, and holds only one chunk of information at a time as an intermediate representation of the current task. In that sense, we can assume in the present study the task in hand requires comparison of two durations, which is presumably carried out by a comparator or an executive unit. Additionally, an articulatory unit also compares the figural relationship between two patterns. In that sense, the poor performance in the irregular rhythm trials of Experiment 1 can be attributed to cost of task switching between these two simultaneous processes. If we consider that standard and comparison are presented only with a brief delay, and also accept that Merrill Garrett is right in saying "parsing is a reflex" (Chomsky, 2017), it would be arguable that in face of a standard pattern, irregularities might be influencing the temporal judgments of the whole duration. This indication entails that figural and temporal encodings are carried out by different mechanisms. Consequently, the data provides counter-evidence for Handel's (1998) proposition that rhythm perception is only related with pattern representation, by pointing the existence of a temporal comparison unit that at least limits the patterns with an estimation of the total duration.

Another outcome of the experimental study is the asymmetry between the different positionings of the irregular stimulus. One possible explanation can be related with the memory pool argument of Taatgen and van Rijn (2011). However, selection of the 'shorter' answers for early note samples and 'longer' option for late note samples indicates a primacy effect, instead of the proposed recency effect for this model, since these answers reflect the characteristics of the first interval. Also, non-musicians' reproduced intervals in Experiment 2 do not change between the irregular sample types –nor among the third interval of all sample types. If the mentioned contamination effects were to be present, at least the third intervals of the irregular samples would be different since they are followed by a shorter and longer interval in late and early note samples respectively. In that case, it would be a proper suggestion to employ a STM component that holds a limited number of items as chunks (Cowan, 2010). Consequently, the indifference intervals reproduced in Experiment 2 by non-musicians, would be related with perceptual encoding of the durations, due to the primacy effect caused by repetition suppression paradigm as discussed in the following section (David M. Eagleman, 2010).

The threaded cognition argument of Salvucci and Taatgen (2008) introduces a computational model for multi-tasking. The units of this model uses chunks of data and the addition of the problem state buffer in a later paper provides a unitary representation of this chunks, resembling to properties of the episodic buffer (J. P. Borst et al., 2010). Referring to the above argument regarding the distractive nature of the expectancy violations created in Experiment 1, due to successive presentation of standard and comparison samples; as the intervals of the whole duration is also a temporal information, whenever the focus is distracted and a representation cannot be formed in the problem state buffer, the salient lateness or earliness of the first interval could be effective in formation of representation as longer or shorter. By the same account, musicians' general tendency to perceive the irregular samples as 'longer' in the Experiment 1 can be explained. J. P. Borst et al. (2010) give an example to illustrate how intermediate representation might be formed in the problem state buffer: "For instance, while solving an algebra problem like 2x-5=8, the problem state can be used to store the intermediate solution 2x=13." If we think in terms of a secondary school student who were just introduced such equations, we would not expect such representations, and on the contrary for an engineer who dealing with complex mathematics, it would be possible to have more complex intermediate representations. Thinking in the same line, a professional musician might have more complex representations of the interval changes in order to provide efficient solutions in the long run. However, in terms of such short samples, it could be reflected as an added temporal span to conduct arithmetic operations concerning the gaps between the expectancy points. These indications rather remain speculative due to limited scope of the experiments and the collected data, but the added time span in the third interval of the late note samples by musician in Experiment 2, supports such complex utilization of the memory system as a result of musical training.

In summary, perception of rhythmic structures includes pattern representations and also a temporal aspect that is at least effective as a limiting factor over the perceived temporal span. It is conceivable to assume that these two elements of rhythm are processed by different units, but there might be overlap of information due to certain attentional or procedural disruptions and consequently the final judgment may be altered. Additionally, musical training might be effective in efficient utilization of this memory mechanism, which results in formation of more complex intermediate representations. While this memory model describes the possible interactions between the figural and temporal representations, the mentioned convergence effects and interval reproductions are believed to be related with the perceptual encoding of the rhythms.

4.3. Temporal Encoding

In order to provide an explanation for the varying reaction of the participants to different event structures and also to account for the differences between the groups the properties of a perceptual mechanism should be identified. Since the tonal structure of the samples do not vary across the experimental stimuli, the temporal encoding of the rhythms should be analyzed in terms of the above mentioned timing mechanisms. Clock-counter models assume an internally produced gridline through counting the clock induced pulses, which then is matched with the perceived intervals and a unitary measurement is provided for an encountered duration (Grondin, 2010). One common assumption of clock-counter models is existence of a switch that starts up the clock unit when an external signal is received indicating beginning of temporal encoding process (Zakay & Block, 1995). Povel and Essens (1985) argue that the nature of the clock ticks are determined according to the accentuation of the perceived rhythmic structure. Accordingly, metrically strong rhythms facilitate the adaptation of an appropriate cock. As the rhythmic complexity increases, it might not be possible to induce an appropriate clock. The configuration of Experiment 1 provides an external clock to match the total duration of the samples. Schulze (1992) provides an error correction model of rhythmic synchronization and proposes that there is no qualitative differences between an internally induced clock and an external clock, since they use the same computations to for calculating the gap between the regular and irregular elements. Eventually, it can be assumed that the standard dictates four counts of 750ms intervals in order to achieve the total 2250ms. On the other hand, the irregular rhythms require a count of 1/3 IOI (250ms) and also the rhythms do not repeat itself to apply iterations of a possible computation to resolve the irregularity. Consequently, if we consider non-musicians, it might be the case that participants lose their focus as they could not represent the necessary smallest grid and carried over by secondary perceptual sources, such as the longness or shortness of the first interval. However, taking Schulze's (1992) model into account, it would be also expected be effective in Experiment 2 that the equivalent internally induced clock -which its failure to find a minimum gird in terms of the 3:4 division between the 4th notes is evident in unequal distribution of the ratios (Figure 12)- to produce different estimations for different samples. As can be seen in Figure 14, the total estimations of the intervals are not significantly different for different sample types. In that respect, the outcomes of the study do not support existence of a beat/accent based internal clock induction in perception of rhythmic structures.

The clock-counter models, besides beat based adaptation of a clock, include distinct approaches to the processing of the clock unit: deterministic (regular interval pulses) and scholastic (random pulses) (Grondin, 2010). The former approach requires an attentional component to explain different perceptions of different temporal and contextual structures. Treisman (1964) presents a suppression account of attention in combination with a deterministic clock unit. In that sense, although the clock unit creates equal interval ticks, suppression of attentional energy towards the repeating stimuli or its increase towards novel stimuli alters the temporal judgments in possible scenarios, with an assumed primacy effect. The Attentional Gate Model (Zakay & Block, 1995) describes a gate unit that opens wide and let more pulses to be transmitted to the accumulator when attention is focused on the time, hence full focus in time would be expected to create an increase in the perceived duration. Similarly, when another attention demanding task is present, the gate closes and the perceived time shrinks as the accumulator receives less pulses. This phenomenon is defended to be valid for prospective duration judgments, where it is known beforehand that the upcoming temporal span should be encoded. In addition to these, as a representative of a scholastic clock argument, the multiple interval encoding model of van Rijn and Taatgen (2008) can be accounted. They argue that a single clock unit producing non-linearly increasing pulses (can be related with the discussed suppression effect) and a linear counter unit would be sufficient to distinguish between different context intervals. In this model, although the attentional load of secondary tasks is deemed to be effective in temporal judgements, perception of different context intervals together is illustrated within a single unit, without the need of an extra attentional control unit or procedure.

The mentioned clock-counter models, despite their different mechanical features, do not predict quantitative changes in the final temporal judgements, in terms of the conditions of the present experimental study –there is no secondary executive task, the tonal characteristics of the samples are the same and only distracting element is the manipulated irregularity. In that sense, they can be compared with the same aspects of the data obtained from the experiments. The mentioned suppression effect in terms of the attentional focus can be related with non-musicians' and also in some trials of the musicians' answers in Experiment 1. The higher activation rate of the first interval might be influential on the final judgment when the irregularity causes a distraction and consequently the change in the direction of the answers towards the temporal position of the second note can be regarded as an encoding related occurrence. It should be noted that musicians' general tendency to longer perception of irregular items, still remains as a storage related phenomenon, as discussed at the above section (J. Borst et al., 2014). Moreover, non-musicians reproduction of the same intervals for early and late note samples in Experiment 2 can be attributed to a clock-counter mechanism, as it could be assumed that the same grid structure is applied to both structures so that the same estimations were performed for early and late notes. Also, the non-linear clock model of van Rijn and Taatgen (2008) draws a coherent model concerning the equivalent total durations reproduced for the whole samples, while sequence of the included intervals change. These descriptions do not contradict with a possible memory chunking system discussed above (Cowan, 2010). Nevertheless, the boosted increase of the shortest interval, compared to small rate of underestimation of the longer interval remains unexplained. In sum, non-musicians' performance is parallel to the arguments of clock-counter models proposed in the referred studies. However, observed asymmetry between the early and late note samples in musicians' estimations of samples in Experiment 2 requires a different perspective, as these models do not predict such diversity for equidistant divergence.

It was argued that between Experiment 1 and 2, imposition of a metric standard altered the perception of the samples. For musicians, while the regular and early note samples could be represented in a flawless manner in terms of their ratios, this balanced reproduction changes in the late note samples. DAT provides explanations for such differences of event structure in terms of a dynamical expectancy profile (Barnes & Jones, 2000). The clock-counter models are unexplanatory in such differences as they assume a template to fit in the perceived duration. The entrainment mechanism predicted by DAT indicates that when an external rhythm and the neural oscillations are aligned, a clear expectancy profile is represented. The oscillatory representations are self-sustaining, stable, adaptive and activate multiple related oscillations that are harmonic with the minimum grid (Jones, 2009). If we consider the musicians' reproduced intervals for the regular and early note samples; the ratios of intervals are equal to each other, the profiles are kept stable over 6 trials of each condition, they align with the structure and the total durations could be represented in balance. Eventually, we can assume that musicians were able to achieve entrainment in those samples. In that respect, we can argue that the disturbance in the late note samples is related with the sequence of short and long intervals. The literature provides evidence that such asymmetry between encoding of short and long intervals could be related with abstraction of a global metric structure (Terry et al., 2016). In that sense it can be assumed that an earlier than expected note happens before the abstracted beat is simulated, while a later than expected note happens after. Following this reasoning, the early violation updates the expectancy profile and assigns a new point, which in the early note samples is the third note as it perceived and reflected in the reproduction. On the other hand, late violation of the second note includes the presumed simulation of the regular second note and the brief duration between this point and the heard late note. In that case, in late note samples actually there is no indication contributing to the expectancy profile in this brief period, but the absence of the expected stimulus. Figure 12 displays that musicians were actually able to reproduce a coherent first interval in terms of its ratio, but failed to do so for the second and third intervals. Accordingly, the shorter reproduction of this second interval might be related with the additional attentional load created by the absence of the stimuli. Similarly, the increase in the third interval can be related with an effort to abide with the total duration. These latter considerations of course remain speculative in frame of the scope of the study.

4.4. Limitations of the Study

Some technical and conceptual errors made during the preparation of the study and consequently, some parts of the Experiment 2 and entirety of Experiment 3 was distracted from the discussion. The statistical analysis of these extracted parts can be found in Annex A. Another limitation of the study was the limited number of participant groups. In that respect, the conclusions drawn from the experiments should be tested with more participants in order to make sure the effects were between the groups and do not reflect individual differences.

The samples used in the experiments consist of four notes, and the irregularities are limited with early and late introduction of the second note with same temporal distance of divergence from the regular note. Consequently, the conclusions drawn from data limited with the presented sample types and it is not certain if these effects would be observed in different setups. Also, they describe the initiation phase of rhythmic adaptation, so the outcomes of the study are not directly applicable to rhythm perception in a musical context.

In addition to these, some of the significant results could not be included in the arguments coherently. The observed asymmetries between the early and late note samples are limited with irregularities acquired thorough 3:4 divisions of the irregular intervals and it is not certain whether such effects can be observed with different divisions. It remains unsolved whether different setups would create altered outcomes.

4.5. Future Research

In future studies, the variables mentioned in the study limitations such as the interval divisions, distance from the expected point and the manipulated note can be tested in different scenarios. Also the specific effects of dictating a standard meter and qualitative differences between using different standards (such as samples allowing 3:4 divisions) can be adopted as research questions. Regarding a possible utilization of different mechanisms in terms of temporal perception can be studied in terms of its activation. In that sense, specifically non-musician participants can be used to search for a presumed strategical point of switching to an entrainment approach.

CHAPTER 5

CONCLUSION

The present study provides evidence supporting that rhythmic irregularities influence the temporal and figural representation of rhythmic structures. These effects are limited with the samples used in the experiments. Also, tonal characteristics of the music were not included in the study. In that respect, the outcomes of the study are not directly applicable to rhythmic adaptation in terms of a musical context. Eventually, the study investigates the beginning phase of such adaptation process with respect to the related memory procedures and the discussed timing mechanisms. In terms of the proposed hypotheses, the results of the experimental study points to certain differences in perception of early and late note violations. The source of these differences is deemed to be related with distinct memory procedures and also with the discussed timing mechanisms with respect to perceptual characteristics of the interval sequences. Moreover, these outcomes entail existence of separate modalities for mental representations of temporal and figural characteristics of rhythmic structures. Regarding the source of these representations and possible strategies applied utilization of these mechanisms, between groups analysis create different profiles for musician and non-musician participants. Accordingly, the study is believed to make a contribution to the existing literature concerning the contribution of musical training to cognitive abilities used in rhythm perception, and provides a foundation for elaboration of these findings in future studies.

Experiment 1 tests the effects of irregularities in accuracy of temporal judgments. In terms of the irregular samples, non-musicians were observed to be more accurate in detecting the total duration of irregular rhythms, while musicians' accuracy rate is lower. Analysis of the wrong answers indicates that non-musicians are influenced by the shortness or longness of the first interval and reflected this tendency in their final judgments. Although musicians also slightly influenced by the nature of the first interval, they tend to perceive the irregular rhythms as longer, if they fail to match the standard and comparison durations. The standard duration was always a regular rhythm, in that sense it was considered as an external clock and the irregular second note was interpreted as an expectancy violation. Consequently, it was argued that non-musicians are more affected by such expectancy violations, when they fail to produce a healthy temporal representation in terms of the goal of the task. Moreover, the drop of the correct answers between early and late note samples for non-musicians raised the possibility that late note samples might be more compelling in frame of the experimental setup. Musicians, as the rate of their correct answers do not change between the irregular rhythms, assumed to apply a unique strategy towards irregularities, aiming to adapt a metric structure due to their training. These findings were considered as memory related outcomes for both groups, since the standard duration has to be kept for comparison.

Experiment 2 includes the reproduction of the regular and irregular samples used in Experiment 1. In regular samples musicians were observed to be resistant to suppression effect that was visible in the structure of non-musicians' reproduced intervals (Barron et al., 2016). Concerning the irregular samples, non-musicians reproduced more or less the same interval lengths, which were supported as an evidence for them to keep solid representations of temporal information. Moreover, the sums of all reproduced intervals were not significantly different among the sample types. This outcome supports that using a standard sample created a distraction in Experiment 1 and influenced the final temporal judgements of non-musicians. Also it indicates that when no standard is present, the asymmetry between the early and late note samples was also absent. On the other hand, this asymmetry was observed to be effective in musicians. Musicians were able to represent the pattern structure of early note samples with high accuracy as they did in the regular samples. However, their reproduction of the late note samples displayed a distraction. It was argued that they were able to adapt a metric structure, even if it was not dictated in form of a standard, and the sequence of short and long intervals might be disruptive in certain orderings. Existence of such asymmetry was interpreted as an outcome of dynamical attending that is assumed to be sensitive to real-time unfolding of events (Jones, 2009). Since sum of musicians' reproduced intervals were also not significant among the sample types, it was proposed that they add an extra space to find out a metric structure within the limits of the total duration, if they fail to adapt to an ongoing rhythm. Accordingly, this space is created in the second interval and compensated in the last interval. In the experimental analysis, this idea is further supported in the Experiment 1, as the standard dictates a metrical grid that is not coherent with the presented irregularities. Investigation of motor synchronization and perceptual components might give a detailed account as to why they perceive the total duration as longer but stay in the limits of the total duration in reproduction. Although the considerations made regarding the relative complexity of late note samples remains speculative, the added time in the third interval of late note samples supports the proposition that musicians might be creating space in the discussed memory model to make estimations in order to find a metric grid.

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APPENDICES

APPENDIX A: EXTRACTED DATA

A.1. Experiment 2 (1800ms Condition)

Experiment 2 was conducted with 2 duration groups as mentioned above. Some technical errors made in Experiment 3, and false configuration of Experiment 1 led removal of 1800ms condition from entirety of the experimental analysis. This annex provides the partial data that was recorded properly. As the 1800ms conditions were randomly presented with the 2250ms condition, considering the stimuli, participants and procedure of the experiment, the Experiment 2 section within the body of the thesis can be used as a reference.

A.1.1. Results

A 2x3x3 ANOVA was used between groups (musician, non-musician) with independent variables containing the response times for each interval (first, second, third), sample type (early 2nd note, late 2nd note regular) and sample duration (2250 ms, 1800 ms). When all the variables are combined a significant between groups effect was observed (F (3,52)= 6.244, p<.002, η_p^2=.258). However, when this analysis is only run for 1800ms samples, the mentioned effect is not significant. Figure 15 shows the descriptive statistics of the ratios of intervals in terms of the sum of the estimated intervals in each trial.

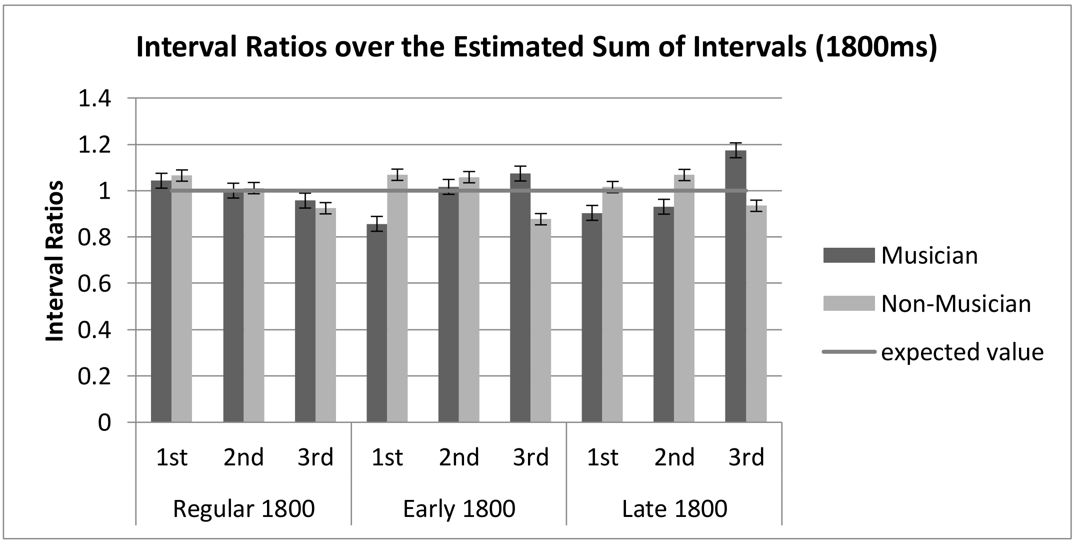

Figure 15. *Normalized values 1800ms condition intervals, according to reproduced total durations in Experiment 2. [Error bars represent SE].*

A.2. Experiment 3

In the third experiment participants are expected to measure and reproduce the total duration of the samples used in the previous experiment – irrespective of the 2^{nd} note being regular, early, or late. The purpose of this task is to obtain control data for the analysis of Experiments 1 and 2. The results of this experiment may rather reflect straight judgements about the temporal perception of the subjects, as the task is very simple and there are no attention demanding procedures other than the perceptual complexity of the irregular samples. Nevertheless, participants were instructed not to pay attention to the internal structure of the rhythm but to focus on the whole duration only.

A.2.1. Method

Participants

The same participants of Experiment 1 also attended to Experiment 2.

Stimuli

The equipment and samples of Experiment 1 are used. Participants are required to reproduce the target duration by pressing the 'v' button two times as indicating the beginning and the end of the whole sample.

Procedure

Experiment 2 is carried out right after Experiment 1. Participants were instructed before the test and received 6 practice trials (1 for each condition) to get accustomed to the task. Before each trial participants should press any key on the keyboard to start listening to the sample. While the track is playing, a fixation dot appears at the center of the screen. Subjects are requested to start reproducing the track after the sample finished and a 'click' phrase is displayed on the screen. They should press the 'click' button two times so as to reproduce the duration passed between the 1^{st} and 4^{th} note of the sample (whole duration=3 intervals). Afterwards, they need to press the key again as instructed on the screen, to start over with a new trial. Samples are presented in a random order, 6 trials for each condition. The Experiment 2 lasted approximately 3 minutes.

A.2.2. Results

Due to an error made in the software Experiment 2 lacks the data for regular 2250ms samples and instead regular 1800ms samples were recorded twice. No significant effect of sample type was found in this analysis. That was indeed the expected result showing that the participants of both groups were able to ignore the internal structure of the samples and produce similar estimations within groups. On the other hand, the between subjects analysis indicates a significant group effect (F (1,18)= 8.464, p<.001, η_p^2=.320). This effect is observed as musicians' temporal estimations (*Late 2^{nd} Note Mean=1594.70, SE=79.72; Early 2^{nd} Note Mean=1550.72, SE=57.21; Regular Mean=1504.31, SE=36,74*) are overall lower than non-musicians (*Late 2^{nd}*

Note Mean=1879.36, SE=122.10; Early 2nd Note Mean=1907.65, SE=108.02; Regular Mean=1863.65, SE=82.79). Figure 13 shows the average estimated values for both groups in the three sample types. These intervals are also compared to the total duration of Experiment 3. The results of this analysis will be discussed later in this section.

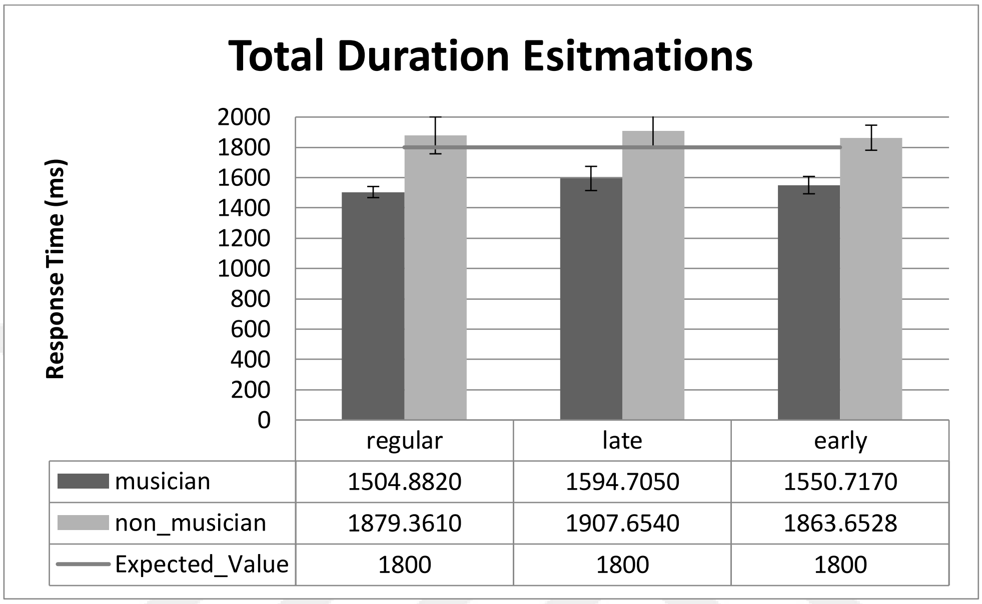

Figure 16. *Average of total duration estimations for 1800ms condition in Experiment 3. [Error bars represent SE.]*

The remaining data for 2250ms early and late note samples were compared to respective 1800ms samples by using ANOVA. A significant sample length effect was observed (F (1,18)= 63.303, p<.001, η_p^2=.779). This effect is insignificant between groups (F (1,18)= 3.750, p<.07, η_p^2=.172). However, between subject analysis indicates a general group effect, (F (1,18)= 5.976, p<.03, η_p^2=.249). The group effect occurs as non-musicians' estimations are below the actual duration for longer samples and above the actual duration for shorter samples. Musicians' estimations are generally below the actual duration (Figure 17).

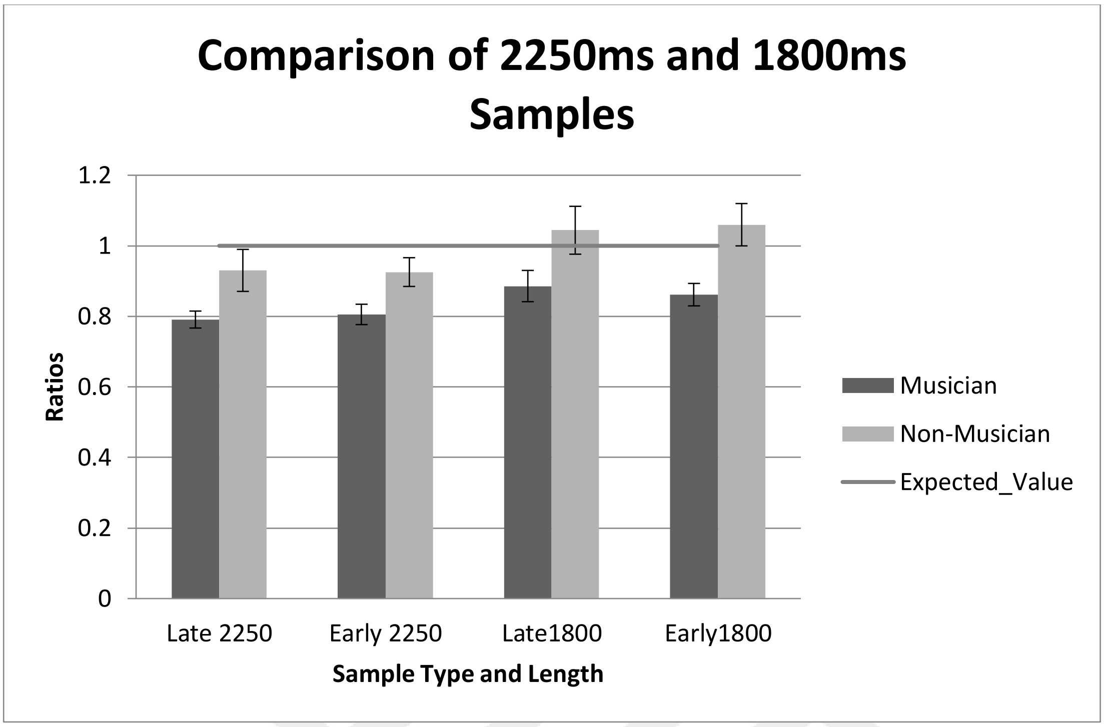

Figure 17. *Average of total duration estimations for irregular conditions of 2250ms and 1800ms samples in Experiment 3. [Error bars represent SE.]*

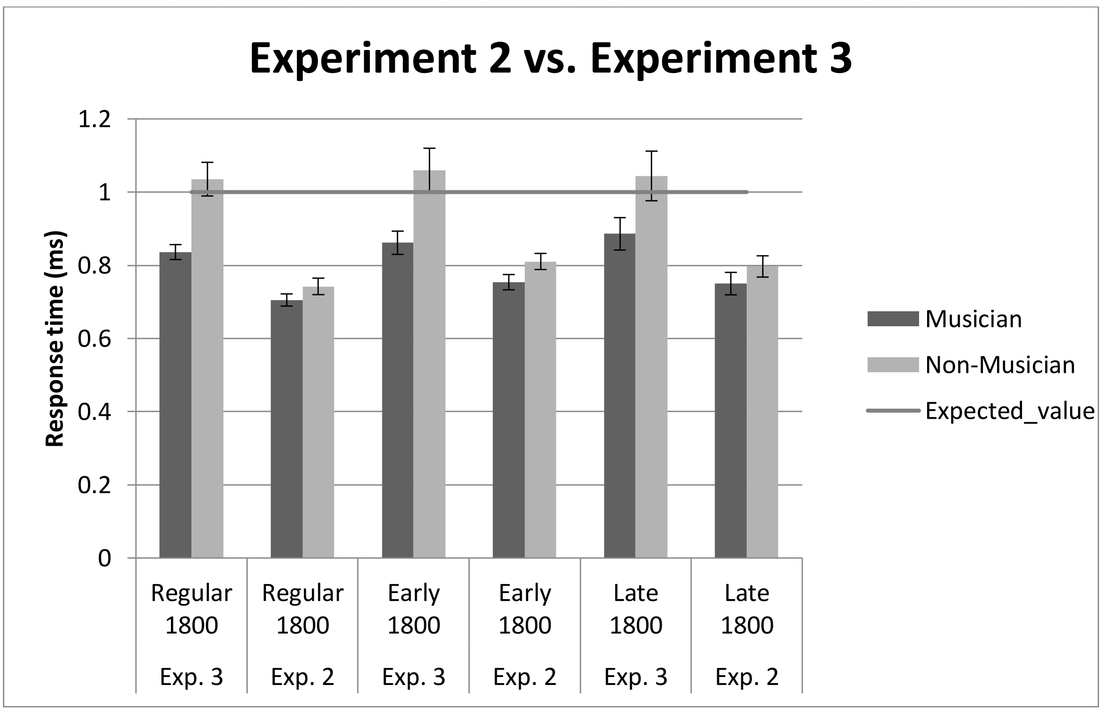

Figure 18. *Comparison of total estimations of 1800ms samples between Experiment 3 and 2. [Error bars represent SE.]*

APPENDIX B: POST-EXPERIMENT SURVEY

Çalışma Sonrası Anket

1- Kaç yaşındasınız? (How old are you?)

2- Cinsiyetiniz nedir? (What is your gender?)

3- Eğitim durumunuz nedir? (What is your education status?)

4- Müzikle ilişkiniz nedir? (What is your relation with music?)
   ○ Hiç ilgilenmiyorum (Not interested at all)

   ○ Dinleyiciyim (I am a listener)

   ○ Amatör Müzisyenim (Amateur musician)

   ○ Profesyonel müzisyenim (Professional musician)

5- Eğer müzisyenseniz, çaldığınız enstrümanı (veya şan, kompozisyon vb.) ve ne kadar süredir çaldığınızı belirtiniz. (If you are a musician, please state what instrument you are playing and for how long?)

6- Deney sürecinin ne kadar eğlenceli olduğunu düşünüyorsunuz? (Can you rate the entertainment level of the study)

   ○ Hiç eğlenceli değil (It was not entertaining at all)

   ○ Orta derece (Moderate)

   ○ Oldukça eğlenceli (Quite entertaining)

İsim Soyad　　　　Tarih　　　　İmza

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B.1. Results of the Survey

Question 4: *What is your relationship with music?*

Answers:

Musicians: *Not interested at all.* - 0

I am a listener (only). – 0

**Amateur musician.* – 5

Professional musician. - 5

Non-musicians: *Not interested at all.* - 1

I am a listener (only). – 8

**Amateur musician.* – 1

Professional musician. – 0

Question 6: *Do you think the experiment was entertaining?*

Answers:

Musicians: *It was not entertaining at all.* - 0

Moderate. – 4

Quite entertaining. - 6

Non-musicians: *It was not entertaining at all.* - 1

Moderate. – 7

Quite entertaining. - 2

**Half of the musicians, also one of the non-musicians represented themselves as amateur musicians. This is their self evaluation. All participants match with the profile defined in the Methodology section.*