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Research Article ♪ **Araştırma Makalesi**

Effects of regular and irregular rhythms on time perception: The role of aksak and non-metric rhythms

Düzenli ve düzensiz ritimlerin zaman algısı üzerindeki etkileri: Aksak ve metrik olmayan ritimlerin rolü

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ABSTRACT

This study aims to examine the effects of regular and irregular rhythmic structures on subjective time perception and, in this context, to investigate the role of aksak and non-metric rhythms. Specifically, the study compares the effects of irregular rhythms, non–metric rhythms, and a control condition (silence) on participants' ability to estimate time intervals. 72 undergraduate students participated in the experiment in a controlled laboratory environment. The participants were randomly divided into control, aksak rhythm, and non-metric rhythm groups. In order to ensure that the initial conditions of the groups were equal, the data collection tools were applied as a pretest. During the subjective time perception assessment process, the groups were asked to perform Time Estimation, Time Production, and Time Reproduction tasks in the retrospective and prospective paradigms. While the control group performed the tasks in silence, the first experimental group was exposed to aksak rhythm, and the second was exposed to non-metric rhythm. During the experiment, the participants were asked to estimate the durations of time intervals presented with the relevant auditory stimuli. The study's data were evaluated in terms of the ratios of estimated times to actual time durations and based on groups' pretest and posttest scores. Additionally, the effects of the gender and age variables of the study group on subjective time perception were examined. The research results revealed significant inconsistencies in time perception among the experimental groups. Participants in the Control and Aksak Rhythm Groups demonstrated more accurate time estimations than those in the Non-metric Rhythm Group. Participants in the Aksak Rhythm Group made estimations close to absolute time as the participants in the control group. Therefore, aksak rhythmic patterns do not appear to have a negative effect on subjective time perception. In contrast, Non-metric rhythmic patterns tend to cause time to be perceived as slower than it is. The variables of gender and age (18-26 age range examined) were not found to affect subjective time perception significantly.

Keywords: subjective time perception, rhythm structures, time estimation, aksak and non-metric rhythms, rhythm and cognition

ÖZ

Bu çalışmanın amacı düzenli ve düzensiz ritmik yapıların öznel zaman algısı üzerindeki etkilerini incelemek ve bu bağlamda aksak ve metrik olmayan ritimlerin rolünü araştırmaktır. Özellikle, aksak ritimlerin, metrik olmayan ritimlerin ve bir kontrol koşulunun (sessizlik) katılımcıların zaman aralıklarını tahmin etme yetenekleri üzerindeki etkileri karşılaştırılmıştır. Kontrollü bir laboratuvar ortamında yürütülen deneyde toplam 72 lisans öğrencisi yer almıştır. Katılımcılar seçkisiz olarak kontrol, aksak ritim ve non-metrik ritim grubu olmak üzere 3 gruba ayrılmıştır. Grupların başlangıç koşullarının eşit olması için veri toplama araçları öntest olarak uygulanmıştır. Gruplardan öznel zaman algısı değerlendirme sürecinde retrospektif ve prospektif paradigmalar doğrultusunda "Zaman tahmini", "Zaman üretimi" ve "Yeniden zaman üretimi" görevlerini yerine getirmeleri istenmiştir. Kontrol grubu görevleri sessizlik içinde yerine getirirken birinci deney grubu aksak ritme, ikinci

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deney grubu ise non-metrik ritme maruz bırakılarak görevleri yerine getirmiştir. Deney sırasında katılımcılardan işitsel uyaranlarla sunulan zaman ve zaman aralıklarının sürelerini tahmin etmeleri istenmiştir. Araştırmada elde edilen veriler hem tahmin edilen zamanların mutlak zamana göre oranları, hem de grupların öntest-sontest puanlarına göre değerlendirilmiştir. Ayrıca çalışma grubunun cinsiyet ve yaş değişkenlerinin öznel zaman algısı üzerindeki etkisi incelenmiştir. Araştırma sonucunda deney grupları arasında zaman algısında dikkate değer tutarsızlıklar olduğu görülmüştür. Sonuçlar, kontrol ve aksak ritim grubundaki katılımcıların non-metrik ritim grubundaki katılımcılardan daha doğru zaman tahminleri sergilediğini göstermiştir. Aksak ritim grubundaki katılımcılar, kontrol grubundaki katılımcılar ile mutlak zamana yakın tahminlerde bulunmuştur. Dolayısı ile aksak ritmik kalıplar, öznel zaman algısı üzerinde olumsuz bir etkiye sahip değildir. Non-metrik ritmik kalıplar zamanın olduğundan daha yavaş algılanmasına neden olmaktadır. Cinsiyet ve yaş (araştırmada incelenen 18-26 yaş aralığı) değişkeni öznel zaman algısı üzerinde anlamlı bir etkiye sahip değildir.

Anahtar kelimeler: öznel zaman algısı, ritim yapıları, zaman tahmini, aksak ve metrik olmayan ritimler, ritim ve biliş

1. INTRODUCTION

The human brain perceives external phenomena from birth and interprets them by its conditions. This process shows that the human mind continues to be structured at every moment and that our mental world expands at every moment. It is debated whether phenomena perceived by the senses and reinterpreted in the brain are copied exactly or adapted into an interpreted image. Time is one of the central phenomena in human life. We perceive it through the senses and reinterpret it in our brains. Time is one of the most fundamental cognitive processes humans have tried to define in the historical process. It has a very decisive effect on the lifestyles of societies as well as on the behaviors of people. The ability to perceive, assess, interpret, and draw conclusions about the future requires individuals and communities to engage in a continuous intellectual movement in the temporal dimension.

Even though there is an absolute concept of time-based on mathematical foundations, our actual experiences show that time is not perceived in absolute terms. For example, although the lesson time is absolutely the same, boring lessons seem very long, and entertaining lessons seem very short. Similarly, although the duration of a football match is exact, boring matches seem to last very long, and exciting matches seem to end quickly. In addition, each individual's subjective perception of time may be different. The perception of time may differ among individuals who experience the same period differently and according to age. For example, an experience with the same length of time may appear different in childhood and adulthood. Time does not flow at the same speed in different periods of life. For example, while time may pass quickly for some individuals watching the same opera, it may be perceived as longer for another. Csikszentmihalyi (1990), known for his flow theory, examined how the perception of time changes when a person is entirely focused on an activity. He showed that time passes faster when we are happy and motivated but is perceived as slower in distress or stress. In the literature on time, the definition of psychological or subjective time is used for this perception of time, which varies from person to person.

Based on the differences in time perception, it can be said that everyone has an internal clock independent of physical time-even though we have set our lives according to a physical clock that we think is absolute. For example, a person who sets his alarm for seven in the morning can wake up on his own at five minutes to seven. Alternatively, a person with a lunch break at twelve can understand that it is lunchtime without looking at the clock. These examples can be increased even more. These examples show that humans have an internal time mechanism. However, the subjectivity of this internal time mechanism requires explanations about how physical time related to the external world is encoded in the brain.

Time is a concept whose reality is assumed. Newton presented an absolute space-time nature in which the universe shares a common "moment.". Kant (2016) argued that time is not an objective reality but a category of consciousness and perception. This idea, known as "Kant's Theory of Time and Space," forms the philosophical basis of modern subjective time theories. According to Kant, time and space are the internal frameworks through which the human mind makes sense of the world. Einstein introduced a flexible and non-absolute concept of time. He stated that time is not an absolute regularity in the universe and that time can change depending on the observer. In other words, he tied time to the observer and called it the theory of general relativity. Following Einstein's theory, the definition of absolute time disappeared and individual time emerged. Bertrand Russell proposed that time is divided into physical and mental. Russell (1915) evaluated physical time as an objective time and emphasized that physical time can be measured if accepted as a starting point. Russell states that for physical time to be measured, the starting point must be considered zero.

On the other hand, if the reference point is accepted as “now,” that is, experienced time, he states that a completely subjective and special mental time structure emerges that is experienced as uniquely ‘now’ instead of objective or physical time. Russell’s mental time is similar to Einstein’s. These perspectives show that subjectively experienced time can differ from what occurs physically or objectively. The French philosopher Bergson (1889) similarly proposed that time has two different forms: scientifically measurable (mechanical time) and internally experienced (continuous time, or “duree”). According to him, subjective time is experienced as a flow or continuity, and this experience is utterly different from mechanical time measurements.

Many theorists have put forward various views on the emergence of the idea of subjective time. William James, one of the founders of modern psychology, was the first to examine how the perception of time changes according to a person’s attention and emotional state. James (1890) developed the “stream of consciousness” concept by arguing that subjective time is related to perceptual processes. Eagleman (2009), a contemporary neuroscientist, has investigated how time perception changes with sensory inputs and attention processes at a neurobiological level. He has particularly examined the brain mechanisms that cause time to be perceived more slowly in situations such as fear or excitement. Husserl (1928/1991), the founder of phenomenology, has deepened the concept of subjective time with his studies on streams of consciousness and time experience. According to Husserl, consciousness constantly connects the past, present, and future and experiences time.

Contemporary cognitive and neuroscience research sheds light on the neural basis of time perception and its relationship with cognitive processes. James (1890) pioneered this field by arguing that attention and mood affect time perception and defined an individual’s time experience as a constantly changing structure with the concept of “stream of consciousness.” Current research on the neural infrastructure of time perception has revealed that various regions of the brain (especially the cerebellum, basal ganglia, prefrontal cortex, and anterior insula) play a role in timing tasks (Coull et al., 2011; Craig, 2009; Ivry & Schlerf, 2008). It has been emphasized that the dopaminergic system, which is particularly associated with attention processes, plays a critical role in processing temporal patterns (Buonomano & Karmarkar, 2002). Concerning the functioning of these structures, time perception arises from the dynamic interaction of different neural circuits rather than a central clock. Buonomano and Karmarkar (2002) state that time is encoded by synaptic plasticity, neural oscillators, and the integration of environmental inputs. Eagleman (2008) has shown that situations such as fear, stress, or distraction cause time to be perceived as either extended or compressed. Emotional centers, such as the anterior insula, are active in these processes. In light of neuroscientific and contemporary cognitive research, it is understood that time perception is shaped not only by the duration of physical stimuli but also by an individual’s level of attention, emotional state, and neural processing mechanisms and that various neurocognitive structures can directly influence this multi-layered system.

Subjective time perception is the capacity of a person to feel or estimate the speed of time passing in their life experience. Subjective time perception is an individual phenomenon and emerges as a result of the individual combining emotional and cognitive inputs with their internal perception of time. There are many studies on variables that affect subjective time perception. Droit-Volet et al. (2011) found that time lasted longer when watching sad scenes and shorter when watching happy scenes. Block et al. (1999) found that time perception accelerates with age. Csikszentmihalyi (1990) reported that time passes quickly or completely forgets time during an activity in which a person is intensely focused and immersed. Wittmann and Paulus (2008) found that stress expands time perception and that people feel time lasts longer when engaged in negative emotions. Eagleman (2008) states that different regions of the brain process time perception and that these processes can change depending on environmental stimuli. Gil and Droit-Volet (2012) reported that time passed more slowly for hungry participants than for full participants. König and Waller (2010) found that people’s perception of time was distorted during multitasking and that time was passing faster. Grondin and Rammsayer (2003) found that when expectations were high, time felt like it was passing more slowly.

There are also studies on the effects of music on time perception. In his study, Fraisse (1982) found that participants who listened to fast-paced music reported that time passed faster, while time was perceived slower in slow-paced music. Zakay (2014) found that time estimates made while listening to music differed from estimates made without music. The study showed that time perception was generally perceived as shorter than it was due to distraction while listening to music. Droit-Volet et al. (2010) reported that participants perceived time faster in energetic and fast music, while they perceived it as longer in slow and relaxing music. Boltz (1998) found that music used to create tension in a film made time feel shorter, while music used in emotional scenes lengthened time. These studies show that perceived time varies depending on the experiences experienced. The word rhythm derives from the Latin "rhythmus", meaning "movement in time". It was transferred to Greek as the word "Rhuthmós" and was used to express the temporary form of something flowing from the 7th century to the 5th century BC. Sub-concepts such as measure, number, transformation, and periodicity, which form its current meaning, were only included in Plato's definition of rhythm in the first half of the 4th century (Benveniste, 1971).

Aksak rhythm refers to rhythmic patterns characterized by asymmetrical downbeat divisions within the metrical structure. In Turkish, "aksak" refers to meter patterns such as 5/8, 7/8, and 9/8, which are formed by combining two and three-beat beats. Unlike standard Western rhythms, which are generally based on symmetrical groups (e.g., 2/4 or 4/4), these rhythm patterns have asymmetrical groups such as 5/8, 7/8, 9/8, and 10/8 (Ayangil, 1988; Feldman, 1996). Aksak rhythms, although they appear irregular, actually contain a certain repetitive pattern. For example, in a 9/8 rhythm (2+2+2+3), the structure repeats continuously in the same way, although the places of emphasis are different. In this case, the rhythm creates a regular asymmetry. The term "aksak" reflects the asymmetrical but generally regular structure of these rhythms within the meter. The theoretical framework of aksak rhythms can be found in the usûl system, a rhythmic structure used in Ottoman classical music. This system organizes rhythmic patterns into cycles, providing a rich basis for improvisation and composition (Signell, 1977). Aksak rhythms, which are used extensively in Turkish Music, can be defined by asymmetrical beat groupings that create a distinct rhythmic feel. For example, a 5/8 rhythm can be subdivided into 2+3 or 3+2. Artists often emphasize different beats within Aksak rhythms, leading to a wide variety of rhythmic expressions even within the same time signature (Ayangil, 1988). These rhythms are an integral part of traditional and folk music in Turkey and neighboring regions, including the Balkans and the Middle East (Stokes, 1992). In Turkish folk music, Aksak rhythms are central to dances and songs, providing a unique rhythmic texture. Aksak rhythms have transcended their traditional roots and have influenced modern genres such as contemporary classical and jazz music (Feldman, 1996).

Non-metrical rhythm refers to rhythmic patterns that do not follow a regular beat or time signature. Unlike metrical rhythms, which follow a structured symmetry (e.g., 4/4, 3/4), non-metrical rhythms lack a consistent meter or regular time divisions. These rhythms often create a sense of fluidity and unpredictability that allows for greater freedom of expression. Non-metrical rhythms are not based on a fixed beat. Composers and performers use non-metrical rhythms to convey emotional depth or evoke certain atmospheres. This structure, found in forms such as the uzun hava or ağıt in Turkish music, is also seen in avant-garde and contemporary classical music (Hasty, 1997). Non-metrical rhythms can be traced back to early musical traditions such as Gregorian chant, which lack a fixed meter. They have also been used in various world music traditions and modern experimental genres (Apel, 1972). Non-metrical rhythms are common in free jazz and other improvisational genres, where the lack of a strict meter allows musicians to explore complex rhythmic ideas (Borgo, 2005).

Understanding how aksak and non-metric rhythmic structures affect subjective time perception is important for studies on cognitive processing, perceptual time, and temporal estimation. This study aims to address this gap in the literature by investigating the effects of aksak and non-metric rhythms, as well as a control condition that included silence, on participants' time estimation abilities. The study aims to explain the differential effects of these rhythmic conditions on subjective time perception using a controlled experimental design.

1.1. Purpose of the Study

The aim of this study is to determine the effects of aksak and non-metric rhythm structures on individuals' subjective time perception. The research question is as follows: Is there a relationship between individuals' subjective time perception and the rhythmic structures they are exposed to? The research presents a series of sub-problems, which include:

To achieve this aim, the following research questions were asked:

1. Do the age and gender of the participants affect subjective time perception?
2. Is there a significant difference between the time perception averages of the control group and the experimental group exposed to aksak rhythms?

3. Is there a significant difference between the time perception averages of the control group and the experimental group exposed to non-metric rhythms?
4. Is there a significant difference in the time perception of the participants exposed to aksak rhythms and non-metric rhythms?

1.2. Significance of the Study

The relationship between subjective time perception and rhythmic structures has not been adequately investigated in the existing literature. This study fills an important gap by examining how different rhythmic structures (especially syncopated and non-metric rhythms) affect individuals' perception of time. The findings will contribute to research in music cognition, rhythm perception, and time estimation by providing insight into how different rhythmic structures shape time perception. Understanding these relationships will offer valuable implications for both theoretical frameworks and practical applications in music education and cognitive psychology.

2. METHODS

2.1. Research Model

"Pretest-Posttest Control Group Experimental Design" was used to obtain the research data. In the experimental design, the research environment was under control, and the extent to which different rhythmic structures affected the subjective time perception was observed. The research is a fully experimental design in that it includes two experimental and one control group, and the samples in the groups were determined by random assignment.

In the experimental method, two experimental groups exposed to different rhytmic variables were used and no intervention was made to the control group. Data collection tools were applied as both pretest and posttest. In order to determine the effect arising from the experimental process, the difference in statistical data was measured by applying pretest and posttest to the experimental and control groups.

The symbolic representation of the model used in the study is given below:

Experimental Group 1	O1	X1	O2
Experimental Group 2	O1	X2	O2
Control Group	O1		O2

O1: Application of data collection tools as pretest

X1: Intervention in Experiment 1 group

X2: Intervention in Experiment 2 group

T2 : Application of data collection tools as posttest

2.2. Sample Group

The study was designed to include a total of 72 participants. The participants were volunteers between the ages of 18-26. The participants were selected from students at university. The participants were divided into three groups: control group, aksak rhythm group, and non-metric rhythm group.

The control group was placed in a quiet environment without a rhythmic structure. The control group was used to isolate the effects of rhythms on subjective time perception. The aksak rhythm group was exposed to a aksak rhythmic structure. The aim was to observe the effects of aksak rhythms on subjective time perception. The non-metric rhythm group was exposed to an irregular rhythmic structure. The aim was to examine the effects of non-metric rhythms on subjective time perception.

The participants were selected from university students between the ages of 18 and 26. The study was conducted on a voluntary basis, and all participants were asked to sign an informed consent form.

Demographic data such as age and gender were collected through the Personal Information Form prepared by the researcher. These data were used to determine the potential effects of variables on subjective time perception.

Table 1

Descriptive Characteristics of the Research Group

Variables	Control		Experimental Group 1		Experimental Group 2	
	Silence		Aksak Rhythms		Non-metric Rhythms	
	N	%	N	%	N	%
Gender						
Female	10	41.7	13	54.2	12	50
Male	14	58.3	11	45.8	12	50
Age						
18-20	8	33.3	7	29.2	8	33.3
21-23	7	29.2	9	37.5	6	25.0
24-26	9	37.5	8	33.3	10	41.7

Table 1 presents the descriptive characteristics of the research group. Participants were divided into three groups: the control group (silence), experimental group 1 (aksak rhythms), and experimental group 2 (non-metric rhythms). In terms of gender distribution, 41.7% of the control group were female and 58.3% were male. In experimental group 1, the proportion of female participants was 54.2%, while male participants made up 45.8%. In experimental group 2, the gender distribution was equal, with 50% female and 50% male. Regarding age distribution, 33.3% of participants in both the control group and experimental group 2 were between the ages of 18–20, while this rate was 29.2% in experimental group 1. For participants aged between 21 and 23, 29.2% were in the control group, 37.5% were in experimental group 1, and 25.0% were in experimental group 2. In the 24–26 age range, the proportions were 37.5% in the control group, 33.3% in experimental group 1, and 41.7% in experimental group 2. These data indicate that all three groups are balanced and comparable in terms of gender and age.

2.3. Data Collection

In the study, the data collection process was organized systematically in order to examine the effects of different rhythmic structures on the participants' perception of time. A total of 72 people who participated in the study were randomly divided into three groups: aksak rhythm group, non-metric rhythm group, and control group. Participants in each group were individually taken to a soundproofed experimental room and listened to rhythm patterns at a constant volume using the same model of headphones. In order to equalize the initial conditions for each participant and to minimize the effect of external variables, the temperature and light conditions of the experimental room were kept constant. Data collection tools were applied to all three groups as a pretest in a quiet environment, and care was taken to ensure that the initial conditions of the groups were equal.

During data collection, participants were asked to listen to aksak and non-metric rhythmic patterns. The aksak rhythm group listened to aksak 5/8, 7/8, 8/8 and 9/8 rhythm patterns, while the non-metric rhythm group listened to non-metric rhythm patterns with no specific pattern. The control group performed the tasks in a quiet environment. The total duration of each rhythmic pattern was 120 seconds. Participants were asked to perform three different tasks according to the retrospective and prospective time perception approaches.

Time Estimation Task: Participants were asked to estimate the duration of the rhythmic structure (120 seconds).

Time Production Task: Participants tried to estimate the elapsed time by pressing the stop button when 55 seconds had passed while the rhythm was playing.

Time Reproduction Task: Participants were asked to estimate how much time had passed after listening to the rhythmic structure starting from any point for 25 seconds.

All these tasks were designed in accordance with the Latin Square design, and each participant participated in the experiment by observing the same rhythmic structures in different orders. In this way, the aim was to minimize order effects and other external variables.

2.4. Data Collection Process

Participants were informed about the purpose and procedure of the experiment. Their voluntary consent was obtained in writing.

In order to equalize the conditions at the beginning of the experiment, to ensure that the participants had similar initial conditions when perceiving different rhythmic structures, and thus to make the experimental results more reliable and valid, the data collection tools were applied to all three groups in a completely silent environment as a pretest. Thus, time perception measurements were made in the groups in a silent environment, and it was tested whether there was a significant difference between the groups in terms of initial conditions.

The data collection process was carried out by taking each participant into the experimental room one by one. The sound insulation and lighting conditions of the experimental room were kept constant. All participants used the same model of headphones, and the sound level was set at the same level for all participants. Necessary precautions were taken to minimize external factors (e.g., room temperature, keeping participants away from distracting elements) during the experiment. Before starting the experiment, the participants were taken to a quiet room and given 15 minutes to rest. In this way, it was tried to ensure that the participants relaxed mentally and physically. Before the experiment, the participants' pulse rates were measured, and it was ensured that they were between 60 and 100.

In order to apply the Latin square pattern, four aksak rhythms were prepared to be played to the aksak rhythm group, and four non-metric rhythms were prepared to be played to the non-metric rhythm group. Four aksak 5/8, 7/8, 8/8, and 9/8 rhythms coded with the letters A, B, C, and D with the same speed and pattern were prepared as sound files to be played to the aksak rhythm group, and four non-metric rhythm patterns with different patterns, coded with the letters A, B, C, and D, were prepared to be played to the non-metric rhythm group. Each rhythmic structure was at 80 metronomes and consisted of 120 seconds. Time perception measurements were made in a silent environment for the control group.

Retrospective and prospective paradigms were used to measure participants' time perception (James, 1890). These paradigms provide a conceptual framework for many experimental studies on perceived time. In this study, participants were asked to perform time estimation, time production, and time reproduction tasks in the method of assessing time perception in line with the retrospective and prospective paradigms.

Participants in the first experimental group listened to aksak rhythm structures, participants in the second experimental group listened to non-metric rhythm structures, and the control group was asked to complete the tasks silently without being exposed to any rhythm or sound. In the experimental procedure, participants were taken to the experimental room one by one, seated in front of the computer, and wore headphones to listen to the rhythm patterns. In the computer environment, when the participant pressed the space bar on the computer keyboard, the rhythm patterns and the stopwatch started working simultaneously, and when the participant pressed the space bar, they stopped simultaneously. Participants were asked to perform three tasks by pressing the space bar on the keyboard. First, after listening to the entire rhythm structure, participants were asked the question, “How long did this rhythm structure last?” and their estimates were recorded. Second, after the rhythm pattern started playing, they were asked to stop the rhythm by pressing the space bar at the 55th second and estimate the duration. Third, a 25-second time interval was listened to starting from any point within the rhythm pattern, and they were asked to estimate the time that passed during this period.

A Latin square design was used to ensure that the rhythms were listened to in the order and that each condition was observed by each participant an equal number of times. A Latin square is a matrix of size n x n and is an arrangement method in which each element appears only once in each row and column. By using a Latin square design, the effects of order and other external irregularities are minimized by applying the experimental conditions in different orders (Wagenaar, 1969; Kirk, 2013). In the study, the Latin Square layout was designed as follows:

Table 2

Latin Square design pattern

Participant	1. Position	2. Position	3. Position	4. Position
1	A	B	C	D
2	B	C	D	A
3	C	D	A	B
4	D	A	B	C
5	B	A	D	C
6	C	B	A	D
7	D	C	B	A
8	A	D	C	B

Table 2 illustrates the Latin Square design used in the experimental procedure. Since the Latin Square design requires the number of participants to be equal to or a multiple of the number of rhythms. Therefore, twenty-four participants were used in each group in the experimental procedure. As indicated in the table above, a matrix was created to ensure that each rhythm appeared once in each position. Each participant listened to the rhythms in the order determined in the Latin Square. Thus, since each rhythm appeared the same number of times in each position, order effects were balanced, conditions were distributed in an orderly manner, a more efficient experimental design was provided, and external factors that could be brought about by random order were reduced.

2.5. Data Analysis

The collected data were analyzed using SPSS (Statistical Package for the Social Sciences). During the analysis process, time estimation, production, and reproduction tasks obtained from each task were examined separately, and mean estimates and standard deviations were calculated for each group. First, all data were reviewed to determine whether there were missing or outlier values. Since no outliers were detected, all responses were used in the analysis process. The Shapiro-Wilk test was used to evaluate the normal distribution of the collected data. According to the results, the assumption of normal distribution was not provided ($p<.05$) in the data of time estimation ($p=.038$), time production ($p=.042$), and time reproduction ($p=.031$) tasks. In statistical analyses, sample size and data distribution are important factors that determine which tests to use. Since certain assumptions, such as normal distribution of data and homogeneity of variances between groups, are not met in small sample studies, nonparametric tests were preferred instead of parametric tests. Nonparametric tests are tests that do not require the data to conform to a specific distribution and generally perform rank or frequency-based analyses. Since these tests do not require assumptions such as normal distribution and homogeneity of variances, they can provide more reliable results in small sample studies (Field, 2013; Siegel & Castellan, 1988). Higgins (2004), also recommends analyzing research data with nonparametric tests when the sample size is less than 30. Mann-Whitney U was used to compare the means of two independent groups, and the Kruskall-Wallis test was used to test the significance of the difference between the means of more than two groups. In addition, effect size (r) values were calculated to statistically evaluate the magnitude of the difference. The effect size was obtained with the formula $r=Z/\sqrt{N}$ according to the results of the Mann-Whitney U and Wilcoxon signed-rank tests. The values obtained regarding effect size were interpreted according to Cohen's classification (0.1=small, 0.3=medium, 0.5=large).

2.6. Ethics

Written informed consent was obtained from all participants before the study began. Participants were clearly informed that their participation in the study was completely voluntary and that they had the right to withdraw from the study at any time without having to provide a reason. It was emphasized that their identities would remain confidential and that personal information would not be included in the research report or shared with unauthorized parties. To ensure compliance with ethical standards, approval was received from the Zonguldak Bülent Ecevit University Human Research Ethics Board on 01.11.2024 with the reference number 517389.

3. FINDINGS

The study investigated the effects of different rhythmic structures on subjective time perception. The results of the pretest analyses on time estimation, time production, and time reproduction tasks performed on three groups, namely control, aksak rhythm, and non-metric rhythm, are presented in Table 3.

Table 3

Descriptive Statistics Regarding Pretest Scores of Groups

Group	Time Estimation (120. Sn) (M ± SD)	Distance Ratio %	Time Production (55. Sn) (M ± SD)	Distance Ratio %	Time Reproduction (25 Sn) (M ± SD)	Distance Ratio %
Control	123.33 ± 5.03	2.75	52.62 ± 3.87	4.33	24.08 ± 1.71	3.68
Aksak Rhythm	125.25±5.42	4.38	53.91±3.42	1.98	24.33±1.94	2.68
Non-metric Rhythm	123.58±9.65	2.98	53.95±4.67	1.91	25.12±2.09	0.48

The control, aksak rhythm, and non-metric rhythm groups were compared in terms of pretest performance in three different time tasks. Table 3 provides descriptive data regarding the pretest results. In light of the descriptive data, distance ratios, mean (M), and standard deviations (SD) in each task were calculated to observe differences between the groups. According to the pretest results conducted in a quiet environment for all groups, it was observed that the means of the control, aksak rhythm, and non-metric rhythm groups did not show significant deviations from absolute time.

In light of the pretest results, the Kruskall-Wallis Test for Pretest Scores was applied to test whether there was a significant difference between the groups. The test results are presented in Table 4.

Table 4

Kruskall-Wallis Test Results Regarding Time Estimation Pretest Scores of Control, Aksak Rhythm, and Non-metric Rhythm Groups

Task	Control		Aksak		Non-metric				
	Median	Mean Rank	Median	Mean Rank	Median	Mean Rank	Chi-Kare	H (df)	p
Estimation	124.500	32.08	126.500	39.23	126.500	38.19	1.643	2	.440
Production	52.00	32.17	53.500	38.40	54.500	38.94	1.565	2	.457
Reproduction	24.00	32.35	24.00	34.44	26.00	42.17	3.389	2	.184

$p < 0.05$

In light of the findings in Table 4, it is seen that there is no significant difference between the groups in terms of time estimation, time production, and time reproduction tasks ($p > .05$. Therefore, it can be said that the initial subjective time perceptions of the groups subjected to the experimental procedure were similar.

Subjective time perception score averages were examined in the context of the gender variable, and the results are presented in Table 5.

Table 5

Mann-Whitney U Test Results of Subjective Time Scores in the Context of Gender Variable

Task	Female		Male				
	n	Mean Rank	n	Mean Rank	U	Z	p
Estimation	72	39.49	72	33.34	537.000	-1.249	.212
Production	72	38.42	72	34.47	576.500	-.803	.422
Reproduction	72	36.93	72	36.04	631.500	-.183	.855

In light of the data in Table 5, it can be said that the gender variable does not create a statistically significant difference in subjective time perception (p >.05). In other words, gender does not have a significant effect on subjective time perception.

Subjective time perception mean scores were examined in the context of the age variable, and the results are presented in Table 6.

Table 6

Kruskal-Wallis Test Results of Subjective Time Scores in the Context of Age Variable

Task	18-20		21-23		24 and above				
	Median	Mean Rank	Median	Mean Rank	Median	Mean Rank	Chi-Kare	H (df)	p
Estimation	126.000	40.91	125.000	33.43	124.000	35.24	1.603	2	.449
Production	53.000	38.87	52.000	21.20	54.000	38.80	2.046	2	.359
Reproduction	24.000	37.41	24.000	37.66	24.000	34.78	.303	2	.859

$p < 0.05$

In light of the data in Table 6, it is seen that the age variable does not create a statistically significant difference in subjective time perception (p >.05). It can be said that the age ranges examined within the scope of this research do not have a significant effect on subjective time perception.

Descriptive data regarding the posttest scores obtained from the experimental and control groups after the experimental procedure are presented in Table 7.

Table 7

Descriptive Statistics on Post-Test Scores by Groups (M ± SD)

Group	Time Estimation (120. Sn) (M ± SD)	Distance Ratio %	Time Production (55. Sn) (M ± SD)	Distance Ratio %	Time Reproduction (25 Sn) (M ± SD)	Distance Ratio %
Control	120.62 ± 5.63	.52	54.37 ± 3.01	1.15	24.62 ± 2.46	1.52
Aksak Rhythm	116.70±7.05	2.75	54.37±5.13	1.15	25.25±5.09	1.00
Non-metric Rhythm	103.29±7.96	13.93	47.83±6.14	13.04	21.25±2.48	15.00

The data in Table 7 show that, in the post-test, the non-metric rhythm group in particular exhibited a higher distance ratio in the time estimation and time production tasks compared to the control and aksak rhythm groups. Based on the data in Table 7, it can be said that the non-metric rhythm group experienced greater deviations than the other groups in the post-test.

The Mann-Whitney U Test for comparing the post-test scores of the control and aksak rhythm groups in three different tasks (time estimation, time production, and time reproduction) is given in Table 8.

Table 8

Mann-Whitney U Test Results for Time Estimation Posttest Scores of Control and Aksak Rhythm Groups

Task	Control		Aksak				
	n	Mean Rank	n	Mean Rank	U	Z	p
Estimation	24	26.60	24	22.40	237.500	-1.042	.297
Production	24	24.57	24	24.33	284.000	-.083	.934
Reproduction	24	23.77	24	25.23	270.500	-.362	.717

$p < 0.05$

The data in Table 8 show that there is no statistically significant difference between the mean scores of the control and aksak rhythm groups in the context of time estimation, time production, and time reproduction tasks. The experimental procedure performed by exposing the aksak rhythm group to an aksak rhythm did not have a statistically significant effect on subjective time perception.

The Mann-Whitney U Test for comparing the posttest scores of the control and non-metric rhythm groups in three different tasks (time estimation, time production, and time reproduction) is given in Table 9.

Table 9

Mann-Whitney U Test Results for Time Estimation Posttest Scores of Control and Non-metric Rhythm Groups

Task	Control		Non-metric				
	n	Mean Rank	n	Mean Rank	U	Z	p
Estimation	24	32.88	24	16.13	87.000	-4.146	.000
Production	24	32.88	24	16.13	87.000	-4.154	.000
Reproduction	24	32.44	24	16.56	97.500	-3.948	.000

$p < 0.05$

When the data in Table 9 is examined, it is seen that there is a significant difference between the control and non-metric rhythm groups ($p<.05$.). Since the mean rank of the control group is higher than the non-metric rhythm group, it can be said that the time estimation task performance of the control group is statistically significantly higher than the non-metric rhythm group. The data show that the mean of the control group in the time production task is statistically significantly higher than the non-metric rhythm group ($p<.05$). The control group also has a statistically significantly higher mean than the non-metric rhythm group for the time reproduction task ($p<.05$). The data in Table 9 generally show that the subjective time perception of the control group and the non-metric rhythm group differ significantly in the posttest scores. It is seen that exposure to non-metric rhythm has a statistically significant negative effect on time perception. According to the results of the Mann-Whitney U test, significant differences were found between the control and non-metric rhythm groups in time perception tasks ($p<.05$). The effect size values calculated to determine the magnitude of these differences were large for time estimation ($r=.60$), time production ($r=.60$), and time reproduction ($r=.57$) tasks. These findings indicate that exposure to non-metric rhythm has a strong and statistically significant negative effect on subjective time perception.

The results of the paired two-sample test regarding the pretest and posttest score averages of the groups are presented in Table 10.

Table 10

Comparison of Pretest and Posttest Averages with Absolute Times

	Groups	Measurement	Mean	Absolute Value	Z	p
Estimation	Control	Pretest	123.33	120	1.676	.094
		Post-test	120.62			
	Aksak Rhythm	Pretest	125.25		-3.645	.000*
		Post-test	116.70			
	Non-metric Rhythm	Pretest	123.58		-4.288	.000*
		Post-test	103.29			
Production	Control	Pretest	52.62	55	-1.626	.104
		Post-test	54.37			
	Aksak Rhythm	Pretest	53.91		-.396	.692
		Post-test	54.37			
	Non-metric Rhythm	Pretest	53.95		-3.441	.001*
		Post-test	47.83			
Reproduction	Control	Pretest	24.08	25	-1.052	.293
		Post-test	-1.052			
	Aksak Rhythm	Pretest	24.33		-.869	.385
		Post-test	25.25			
	Non-metric Rhythm	Pretest	25.12		-4.035	.000*
		Post-test	21.25			

*p < 0.05

The data in Table 10 show that there is no significant difference between the mean pretest and posttest scores in all three tasks of the control group in terms of absolute time distance (p >.05). While no significant difference was observed between the mean pretest and posttest scores in the 25-second time production and 55-second interval reproduction tasks in the group exposed to aksak rhythm, a significant difference was observed between the mean pretest and posttest scores of the 125-second time estimation. When the mean scores are examined, it is seen that the time estimation posttest score of the aksak rhythm group decreased statistically significantly. While the aksak rhythm group average point was 125.25 in the pretest, this value decreased to 116.70 in the posttest. It is seen that there is a significant difference between the mean pretest and posttest scores of the group exposed to non-metric rhythm in terms of absolute time distance (p<.05). When the mean scores are examined, it is seen that the mean posttest scores of the non-metric rhythm group in time estimation, time production, and time reproduction decreased statistically significantly. In the non-metric rhythm group, while time estimation was measured as 123.58 in the pretest, this value decreased to 103.29 in the posttest; while time production was recorded as 53.95 in the pretest, this value decreased to 47.83 in the posttest; while on-time reproduction was recorded as 25.12 in the pretest, this value decreased to 21.25 in the posttest. The effect size values calculated to determine the magnitude of these differences were r=.74 (large effect) for the time estimation task of the aksak rhythm group, r=.88 (large effect) for time estimation in the non-metric rhythm group, r=.70 (large effect) for time production, and r=.82 (large effect) for time reproduction. These findings reveal that exposure to non-metric rhythm, in particular, significantly and strongly disrupts subjective time perception.

4. CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

This study aimed to investigate the effects of aksak and non-metric rhythmic structures on subjective time perception. The results obtained from the study revealed that the aksak rhythmic structure did not cause significant differences in the subjective time perception of individuals in short periods. However, it was observed that aksak rhythmic structure caused deviations in subjective time perception when the periods were longer. Non-metric rhythm structure caused deviations in time estimation in terms of subjective time perception. It was found that subjects exposed to aksak rhythms produced more stable results in time estimation, while non-metric rhythms caused significant deviations. The findings support that rhythm structures are an important variable in terms of subjective time perception.

In terms of the study results, participants exposed to non-metric rhythm showed more deviations in time estimates compared to the control and aksak rhythm groups. Therefore, it can be said that aksak rhythms tend to stabilize time perception in short-term time periods and allow individuals to establish rhythmic reference points in their estimation processes. Therefore, it can also be said that aksak rhythms create an internal metronome in the individual's subjective time perception in short periods, and this synchronization positively affects subjective time perception by better perceiving time intervals.

It was observed that participants exposed to non-metric rhythms made significant errors in time estimation. It can be said that non-metric rhythms cause temporal uncertainty and confusion because they create difficulty in developing rhythmic references. The study results showed that non-metric rhythms disrupt the mind's time processing and cause the perceived duration to be shorter than it actually is. This was much more evident in time reproduction tasks and created inconsistencies in the individual's temporal memory processes. Therefore, it can be said that non-metric rhythms affect internal synchronization and attention processes and create deviations in perceived time.

The control group, who performed the tasks in a quiet environment, had higher time estimation accuracy than the non-metric rhythm participants. The control group appears to process subjective time more accurately because they were in a simple environment devoid of external sources that could affect their auditory temporal perception. The high accuracy of the control group suggests that the existence and structure of different rhythm types have disruptive effects on subjective time perception.

Music directly affects emotional and mental processes. Non-metric rhythms can complicate the subjective perception of time by causing complex and contradictory emotional reactions in the individual. Evidence that estimated time intervals are shortened under a non-metric rhythm comes from the fact that attention and concentration are interrupted, and time is felt to pass longer than it actually is. The sense of complexity and tension in non-metric rhythms gives the impression that time is longer than it actually is.

Research findings indicate that the effects of rhythmic structures on subjective time perception may have important application areas in both music education and music therapy. The potential of irregular rhythms to stabilize short-term time perception may contribute to the processes of individuals developing attention, increasing timing skills, and creating rhythmic references. This suggests that irregular rhythms can be used as a pedagogical tool in the design of materials aimed at improving attention and time awareness in music education. On the other hand, the neurocognitive effects of rhythmic structures can also be evaluated as a therapeutic stimulus on individuals experiencing impairments in time perception (e.g., attention deficit, Parkinson's disease). In this context, music-based interventions can be developed by utilizing the effects of rhythmic structures on individuals' internal timing and attention processes.

While the findings of this study provide important information about the effects of aksak and non-metric rhythms on the subjective perception of time, it also has some limitations. The study was conducted only in a specific age group (university students aged 18–26), and potential effects were not observed in different age groups. It is recommended that further research be conducted on the effects of time perception on different age groups, the neurological effects of the rhythmic structure of music, and the effects of the rhythmic structure of music on time perception in daily life.

In conclusion, the results of this study reveal the effects of rhythmic structures on individuals' subjective perception of time and support the effect of music on cognitive processes. While aksak rhythms support the accuracy of time perception, non-metric rhythms can lead to deviations in time perception. These findings show that rhythms are an important variable affecting subjective time perception and emphasize the role of rhythmic structures in psychological and cognitive processes.

Ethical approval

The study was approved by Zonguldak Bülent Ecevit University Ethics Committee (date: 16.12.2024, number: 534577).

Author contribution

Study conception and design: İK; data collection: İK; analysis and interpretation of results: İK; draft manuscript preparation: İK. All authors reviewed the results and approved the final version of the article.

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