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"Do humans prefer repetition or regularity in rhythmic patterns?"

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We are what we think. All that we are arises with our thoughts. With our thoughts, we make our world.” The Buddha

Abstract English

Music is a fundamental part of the human condition, reflecting our cognitive abilities. It is common for people to synchronize their body movements with rhythm. A variety of parrots was found to synchronize movement with a rhythmic pulse. Following these findings, a recent study showed that female budgerigars are interested in both elements of rhythmic stimuli consisting of repetition and regularity. Since we do not know which rhythmic element matters for humans, making it is hard to compare with budgerigars.

Therefore, in the present study, I want to answer this question: Do humans prefer repetition or regularity in rhythmic patterns? I presented participants with four types of stimuli, repetition, regularity, and both or neither, in a three-condition acoustic place preference paradigm (where participants were allowed to explore an environment and choose whether to listen to sound or silence). I quantified how much time participants spent with the four types of stimuli relative to each other as a measure of relative attractiveness.

The results showed a significant preference for regularity over arrhythmic stimuli and a significant preference for rhythmic over arrhythmic stimuli. The survey results also showed a preference for rhythmic over other stimuli and a preference for regularity over arrhythmic but not repetitive stimuli.

In conclusion, the results from budgerigars and humans suggest that the appreciation of rhythm is not unique to humans. These findings support that regularity is important for synchronization, social bonding, and dance in humans. While female budgerigars do not use regularity and synchronization in the group.

1. Introduction

Music is a basic part of human condition and is a reflection of our cognitive abilities. It is the result of thousands of years of neurobiological evolution and is involved in many basic human needs (Schulkin et al., 2014). Let first focus on defining music. Music is a complex phenomenon composed of interdependent parts. In simple terms, it is a sequence of events that occur over time, referred to as a specific sequence of durations (Wade, 2004).

Darwin (1871) saw music as a puzzle in the theory of evolution. Today, researchers have different theories, suggesting that music might have evolved for specific reasons. For example, Miller (2000) discussed that music might serve as a signaling system for mate choice, meaning that our evolution of musical skills could be grounded in communication linked to mate selection. This idea suggests that musical expression may have played a role in information about an individual's fitness and desirability as a potential mate. Researchers such as Hagen & Bryant (2003) and Merker et al. (2000) suggest that musicality may have evolved as a means of promoting coalitions. According to this perspective, music serves as a tool for individuals to signal their commitment to group dynamics, promoting social cohesion and cooperation within communities. Yet another Interesting hypothesis proposes that musicality evolved to calm infants, as suggested by Falk et al. (2014), and Mehr et al. (2017). Some studies consider music an evolutionary byproduct of social bonding, exploring it as a combination of genetic and cultural influences. These studies delve into the idea that the development of music and musicality is shaped by a complex interplay between genetic predispositions and cultural practices. In this perspective, music is not merely a cultural artifact but has roots in our evolutionary past, serving a role in fostering social unity and communication. Understanding the evolutionary roots of music involves untangle the links between our genetic and cultural contexts that shape musical expression. It provides a window into the multiple origins of this universal human behaviour (Savage et al., 2020).

Honing (2018) and Savage et al. (2021) suggest it is important to clearly separate music from musicality. "Music" includes all kinds of things like songs, instruments, and dance styles that people create for making music. In contrast, "musicality" searches into the foundational biological capacities that enable humans to engage with and contribute to the world of music. This involves the complex interaction of cognitive and sensory mechanisms that facilitate the perception, interpretation, and production of musical elements. "Musicality" goes beyond the tangible cultural manifestations of music, exploring the underlying cognitive and perceptual processes that make our musical experiences possible and contribute to the universal nature of musical expression across diverse cultures and societies (Savage et al., 2021). The main conceptual framework I will be exploring is musicality. My research will be conducted on humans. To narrow down the research, the focus will be mainly on the preference of rhythmic elements (repetition and regularity) as a component of music. Let us have a definition of rhythm.

Rhythm i**s** an essential dimension of human music. Repetition and regularity are two important elements of rhythm, for example, regularity is important for synchronization and repetition helps to unify melody and symmetry. It is important to know about the human perception of rhythm. There are several theories that have been developed about rhythm perception. When it comes to understanding rhythm in music, The theory of Lerdahl and Jackendoff (1983) is about When it comes to understanding rhythm in music, the theory divides rhythm into two parts: grouping and meter. Grouping is like dividing music into different sections, and meter involves a regular pattern of strong and weak elements, with accents being important. Todd & Lee's model (1999) agrees with this theory and uses special filters to find rhythmic events, suggesting that there's more structure in sound than we thought. Computational models, such as those of Povel and Essens (1985), look at small ratios and how events are split to understand meter. Longuet-Higgins (1979) look at rhythmic continuity and how long notes help predict when things start. Parncutt's model (1997) focuses on the importance of pulse strength and converts event lengths into accents. Desain's model (1992) deals with the challenge of ensuring that beats are consistent by adjusting intervals. Large and

Kolen's model (1994) uses oscillating units to match external rhythms, successfully keeping up with the beat. Todd's multiscale filter model combines several aspects, even taking into account foot-tapping. Cooper and Meyer (1963) introduce the idea that rhythm has two sides: how it sounds and its structure.

In short, understanding rhythm involves looking at timing, how things sound, and how rhythmic structures are organised. Different models give us different ways of seeing and learning about how people perceive rhythm in music (Pierce, J. R., 1999). For example, Nettl (2000) showed that every culture has some kind of music that has a periodic beat to which listeners synchronize their movements. In another study electroencephalographic and visual preference research in infants indicates that our sensitivity to the correlation between music and movement develops at a very early stage in life (Phillips-Silver &Trainor 2005). Their findings suggest that for humans, there is an innate reward associated with synchronizing body movements to the rhythmic beats of music.

Music recently is seen as a phenomenon unique to humans (Hauser, M.D. & McDermott, 2003). However, it has been proposed that many of the features of music cognition are associated with brain functions shared with other animals (Fitch, W.T., 2006). Therefore, one-way to understand the origins of musicality, including our innate ability to perceive, appreciate and create music, is to explore its components in other species (Honing et al., 2015).

Animals produce sounds, they are not always pleasant to us, but they have meanings (Schulkin et al., 2014). They interact through sound production and perception. Animals employ acoustic signals, like bird songs and cricket chirps, to transfer information crucial for reproduction and survival (Baker et al., 2019). For example, to attract a mate, insects produce a wide range of songs, using pulses repeated at regular intervals (pulse song) for courtship (Baker et al., 2019). Many birds, as well as non- human primates, use acoustically different vocalizations in different situations (Curio, 1978). In the animal kingdom, bird song is one of the most recognizable and studied vocalizations. Extensive research has explored the role of male song, emphasizing its importance

in activities such as male-male competition and mate choice (Collins, 2004). Conversely, the songs of female birds are believed to convey aspects such as territoriality, pair-bonding, mate defense, and attraction, as elucidated in Langmore's research (1998, and associated references). This suggests that female birds employ vocalizations for a diverse range of communicative purposes within their social and reproductive contexts.

There are few studies to show that birds, like mammals and non-human primates, can use intrinsic ability to learn in their use of context- specific vocalizations (Seyfarth et al., 2010). Many species use highly coordinated forms of inter-individual temporal coordination, such as synchrony and antiphony, and appear to be specialized (Ravignani et al., 2014). Some studies conducted on animals and suggests that animals might have more advanced auditory perception than previously thought. For example, in 1984, Porter and Neuringer conducted acoustic discrimination tasks by testing pigeons' ability to differentiate between musical compositions by distinct composers. This study prompted further exploration into the realm of complex auditory stimuli discrimination across various animals. Notably, Watanabe et al. (1999) extended these investigations to Java sparrows (*Padda oryzivora*), examining their capacity to discriminate among compositions from different composers. Simultaneously, Chase (2001) delved into the auditory prowess of koi carps (*Cyprinus carpio*), focusing on their ability to categorize blues and classical music. These studies showed that animals like pigeons, Java sparrows, and koi carps could distinguish between different musical compositions or genres, revealing their ability to process complex auditory information. However, it is crucial to recognize that the extent and specifics of these abilities can differ among species. Further research is needed to explore the cognitive capacities of various animals in understanding and categorizing auditory stimuli.

In the recent studies by (Large 2000; Patel et al., 2005; Repp 2005; Patel, 2006; Fitch, 2013) suggested while many animals show sensitivity to temporal patterns, only a few have demonstrated the ability to coordinate their movements to an acoustic rhythm, known as beat perception and synchronization (BPS). The beat is the underlying pulse of music. It has been shown perceiving

and synchronizing musical beats involves both auditory and motor connections, with strong associations across brain systems and between perception and action (Patel et al., 2005). In human, motor systems are automatically and naturally activated when they listen to music (Nettl, 2000). People from all over the world often naturally and easily move to the beat when they hear rhythmic music, enjoying the experience (McNeill, 1995; Patel et al., 2005).

In 2007 a video of a sulphur-crested cockatoo (*Cacatua galerita*) dancing to music was released, which has fascinated many researchers. This video shows how a bird named "Snowball" is able to synchronize his movements, such as bobbing his head and tapping his feet, to the beat of music (the video is available by searching YouTube for "snowball dancing cockatoo"). It gave scientists the idea that an animal could synchronize to music. Therefore, Patel et al. (2008) carried out some experiments with Snowball. They found that Snowball synchronized with the music (slowing down or speeding up a song). Hasegawa et al. (2011) showed budgerigars are able to engaging in BPS. In both studies, the research sheds light on the rhythmic adaptability exhibited by parrots, highlighting their capacity to synchronize motor actions with various auditory stimuli. These insights contribute to a deeper understanding of the rhythmic abilities displayed by certain avian species. Following these findings, Patel (2021) suggested that the reason for BPS in humans and parrots is that both species are vocal learners. Parrots are one of the few species that learn their vocalizations via the displaying to vocal conspecifics.

BPS depends on the two areas of the brain (vocal learning and motor) that are directly connected in vocal learners, the part that initially evolved to help animals learn complex vocalizations (Patel, 2006). Animals learn their unique sounds by listening to others; this helps them create their own vocalizations (Tyack, 2020). However, not all species possess the ability for intricate vocal learning. Presently, recognized vocal learners are primarily found among cetaceans, pinnipeds, primates (only humans), and specific types of birds. Among birds, the noteworthy vocal learners are predominantly songbirds, parrots, and hummingbirds (Huang et al., 2023).

This suggests that while some animals, including specific mammals and birds, have the capacity for sophisticated vocal learning, it is not a universal trait across all species (Huang et al., 2023). Further studies have shown that while many species with BPS are vocal learners (e.g., humans, several species of parrots and elephants), there are exceptions, such as Ronan, the four-year-old Californian sea lion (*Zalophus californicus*), who was evaluated for her entrainment capabilities and was trained to move her head in time to music, although she was not a vocal learner (Cook et al., 2013). This hypothesis focuses on the sea lion's ability to perform entrainment to (1) rhythm through multiple sensory channels (2) different tempos, and (3) a tempo that was integrated into complex rhythmic-melodic elements. She mastered all challenges, showing its ability to synchronize motor behavior to an auditory beat through entrainment. They investigated the sea lion's abilities in relation to Patel's (2006) hypothesis of beat perception and synchronization. In another study, it was found that rats could move to the beat of music, just like humans, even when there is no clear reason for them to do so (Ito et al., 2022). In contrast to animals that can learn vocalizations, rats do not have this ability. This finding provide a challenge to the vocal learning hypothesis. Despite recent findings, there is still a need for more research and information on parrots and their ability for beat perception and synchronization. These researches will help identify which aspects of music cognition are likely to be based in brain functions shared with other animals (Fitch, W.T., 2006; Hauser, M.D. & J. McDermott, 2003).

Recently there has been focused on parrots for their amazing ability to synchronize their movements with a rhythmic pulse (Schachner et al., 2009). Understanding the mechanisms of this synchronization not only adds to our knowledge of bird cognition, but also adds a level of detail to the wider discussion of the presence of rhythmic abilities across species in the animal kingdom. This research provides valuable insights into the many ways in which animals, including parrots, engage with and respond to rhythmic patterns in their world, questioning previous ideas about the exclusivity of rhythmic coordination in humans. Acoustic preferences are connecting to rhythmic understanding because they influence how individuals perceive, interpret, and engage with rhythmic patterns in music and engage

with the temporal aspects of rhythm, including the speed and timing of musical events.

The majority of prior research on acoustic preferences has employed a place preference paradigm (Hoeschele et al., 2016). Place preference paradigm is an experimental approach used to study the acoustic preferences of non-human animals where, allows animals to move freely in a controlled environment, often an area, where different sounds (stimuli) are played in different locations. The aim is to observe and analyze their decisions and movements in response to different auditory stimuli. This method enables scientists to observe and quantify the animals' choices, providing valuable insights into their acoustic preferences. By allowing animals to freely explore and express their preferences in a spatial context, researchers gain a more comprehensive understanding of how different sounds impact their behavior and spatial decisions. Here are some key points that has been mentioned by recent studies (e.g. Hoschele et al. 2015) to consider when exploring this paradigm. Naturalistic environments: The aim of the place preference paradigm is to recreate a more naturalistic environment in which animals can make choices based on their acoustic experiences.

This will give researchers a better understanding of how animals respond to different sounds in their natural habitats. Behavioral observations: Scientists closely monitor the animals' behavior, including the amount of time spent at each location with a particular sound, the frequency of movement between sound sources, and any other observable responses. This allows the acoustic preferences of the animals to be quantified and analyzed. Species-specific considerations: Different species may have different preferences for sound. Some animals may be attracted to certain sounds or patterns, while others may be repelled. Researchers must take into account the natural history and ecology of the species they are studying. Ecological relevance is evident in decoding animals' acoustic preferences, which may indicate associations with food, mating, or safety. These preferences carry implications for conservation and habitat management. Despite its utility, the place preference paradigm has limitations. Factors like experimental setup, environmental novelty, and individual variability among animals can influence results. Rigorous experimental design and

statistical analysis are essential for reliable conclusions.

Leitão et al. (2006) showed a correspondence between the results of place preference experiments conducted in controlled laboratory settings and those observed in the field when studying conspecific song preferences. Such congruence between controlled and natural environments enhances the generalize ability of research outcomes, providing a more comprehensive understanding of the factors influencing animal behavior and preferences across diverse contexts. In the research study of music-related preferences, place preference experiments have demonstrated clear patterns. Specifically, these studies indicate that newly hatched chicks (*Gallus gallus*) and humans show a preference for melodies featuring consonant tonal relations over dissonant ones, while this distinction is not observed in cotton-top tamarins (*Saguinus oedipus*) (McDermott and Hauser, 2004; Chiandetti and Vallortigara, 2011). Further studies have shown that chimpanzees prefer music to silence (Mingle et al., 2014), while cotton-top tamarins have shown a preference for silence over music (McDermott and Hauser, 2007).

Recently Hoeschele et al. (2016) conducted a comparative experiment to investigate the possibility that budgerigars like humans, enjoy rhythm the way we do. They attempted to determine whether humans and budgerigars show a preference for rhythmic versus arrhythmic acoustic temporal patterns, using a place preference paradigm where both species were presented rhythmic and arrhythmic sound patterns. Both species were allowed to explore the environment for 5 minutes after which the researchers quantified how much time species spent in the proximity of each stimuli. The results for humans showed that participants spent more time with rhythmic stimuli than with arrhythmic stimuli. They also preferred rhythmic stimuli when asked directly in a post-test survey. The budgerigar results showed no preference. Further examination of the budgerigars' results revealed a sex effect. Male budgerigars spent more time with arrhythmic stimuli, whereas female budgerigars spent more time with rhythmic stimuli. These results support the idea female, but not male, budgerigars are attracted to rhythmic stimuli (Hoeschele et al., 2016).

Since then, two of the master's students in Hoeschele's group (Afroozeh et al. in prep; Kopaç et al. in prep) conducted a study as a continuation of Hoeschele et al.'s (2016) study. They used a place preference paradigm with three locations. This apparatus differed from the two-sided place preference paradigm used in (Hoeschele et al., 2016). In the two-sided place preference paradigm, individuals have only two choices, but in the three-sided place preference paradigm, the birds were allowed to choose what they wanted to hear, whether they wanted to hear rhythmic, arithmetic, or silence. Then it is easier to say whether the animal enjoyed the stimulus based on whether it was more attracted to or less repelled by a particular stimulus.

The results showed that the males spent the most time in silence, and the females spent significantly more time in the rhythmic perch. Now the question is, what do the females like about the rhythmic stimuli? The problem with the rhythmic stimuli used in their study was that the rhythmic stimuli had both aspects of rhythm (repetition and regularity). Therefore, it was not clear which aspect of the rhythmic stimuli (repetition or regularity) was important to them. Therefore, they used two sets of new stimuli, only repetition stimuli and only regularity stimuli. Female budgerigars spend about equal amounts of time on regularity and repetition stimuli. This result showed that both factors of rhythm seem to be important to them.

1.1.Aims of this thesis:

Following on from the recent studies described above on female budgerigars (Afroozeh et al. in prep; Kopaç et al. in prep), which showed both factors of rhythm repetition and regularity seem to be important to female budgerigars. Present research therefore builds upon on the previous study to see if humans show preference towards regularity or repetition in a similar experimental design by quantifying the time spent in the proximity of specific sound patterns presented through an acoustic place preference paradigm. Thus, I want to answer the question:

Do humans prefer repetition or regularity in rhythmic patterns?

Accordingly, I used a three-location place preference paradigm, as initially suggested by Hoeschele et al. (2016) and subsequently applied by Kopaç et al. (in preparation) in their investigations involving female budgerigars. I intentionally used the same experimental apparatus and stimuli as in the budgerigar study. This was done to maintain methodological unity and to facilitate meaningful comparisons. This approach ensures that the conditions under which participants and budgerigars were tested remain as similar as possible, thus allowing for a robust and valid comparison of results from both studies. This experimental design involved presenting participants in my study, with an environment featuring three distinct locations; two of the three locations were associated with two different stimuli and the third one was allocated to silence. Within this setup, participants were afforded the opportunity to freely explore the designated space, encountering a variety of sound sources placed throughout.

2. Materials and Methods

2.1. Compliance with ethical standards

Adherence to ethical standards was paramount throughout all procedures involving participants in this study, and these protocols were aligned with the principles outlined in the Declaration of Helsinki (1964). Prior to their involvement, participants were presented with a comprehensive informed consent form. This document explicitly communicated the nature of the study, its objectives, and the procedures involved. Importantly, participants were told that their participation was totally voluntary and that they had the right to leave the study at any time without adverse consequences. This level of trust and respect for participants' privacy helped to ensure that the research was conducted in an ethical manner and in line with current guidelines for the ethical treatment of human subjects in research.

2.2. Human subjects

I conducted the experimental study with a cohort of thirty-eight adult human subjects, aged

between 18 and 43 years, including 9 males and 29 females. The research was carried out at the Acoustics Research Institute (ARI) of the Austrian Academy of Sciences. Notably, the participants had diverse musical backgrounds, with an average of 5.92 years of musical training (SD = 5.032), ranging from no prior musical training to 20 years of experience. Recruitment was facilitated by the Vienna CogSci: Study Participant Platform, an online service where potential participants could register and participate in experiments in exchange for financial compensation. The main participants were students from the University of Vienna, none of whom had any previous experience of this particular experiment. Geographically, the participant pool represented a broad spectrum, with the majority hailing from European countries such as Austria, Hungary, Poland, Greece, Slovenia, Romania, Estonia, Ukraine, and Russia. Additionally, a small percentage originated from non-European countries, including Iran, South Africa, Turkey, India, Colombia, and the USA, contributing to a diverse and globally representative sample.

2.3. Test Apparatus

2.3.1 Acoustic place preference paradigm

Participants were tested in the anechoic chamber of the Acoustics Research Institute (ARI) of the Austrian Academy of Sciences. The dimensions of the anechoic chamber were 5.5 m x 5.5 m x 2.5 m (interior 6.9 m x 7.0 m x 3.1 m (exterior, the space within the space was double-skinned and the distance between the outer shell and the inner cabin was 10 cm). The designated test area was demarcated within the anechoic room by a circular boundary marked conspicuously with red tape on its periphery, situated on the right side of the room. Within this circumscribed space, three distinct locations were identified and delineated using black and white chequered tiles. These marked locations provided a visually distinct and defined environment for the experimental procedures, ensuring a clear and consistent spatial arrangement for participants during the study. The layout of the marked locations was

systematically organized, with each tile positioned precisely 120 cm apart, and each tile featuring a footprint to signify that participants were encouraged to step on them. Notably, within each designated location, an infrared beam system was implemented, consisting of two sensors strategically placed on opposite sides. This infrared beam setup served the crucial function of continuously monitoring and recording the precise position of the participants within the designated areas, thereby ensuring accurate data collection and analysis throughout the experimental proceedings. An interruption of the infrared beam for more than 300 ms triggered the playback of stimuli through the adjacent loudspeaker (FE108 full-range loudspeaker, Fostex, Tokyo, Japan; frequency range 200-16 000 Hz,), which was placed on a tripod in the center of the test area via on the computer (HP Pro3500 Series- EXPBLAU-ALT-Intel (R) Core (TM) i5-3470 CPU) and an Arduino (see info) Uno REV 3 chip (BCMI, Turin, Italy).

Within the three-place preference apparatus, the experimental design involved the presentation of two stimuli concurrently across six distinct experimental sessions. This approach was adopted to facilitate a comprehensive comparison across four types of stimuli, systematically arranged using a Latin square design. The Latin square allowed for a balanced and systematic allocation of the different stimuli across the experimental sessions and participants. Notably, the presentation of these stimuli triggered an interruption of the infrared beam at two specific locations. Meanwhile, the third location within the circular area was intentionally designated as a silent zone, offering participants the option to experience an absence of auditory stimuli. This location also varied across all sessions. The experimental functionality was programmed in Python and via an Arduino, allowing precise control over stimulus presentation and data collection. The lab was equipped with a video surveillance system. This system allowed me to observe the participative time, ensuring vigilant monitoring of their actions, movements, and responses throughout the experimental sessions. Figure 1 shows a diagram of the participant test apparatus.

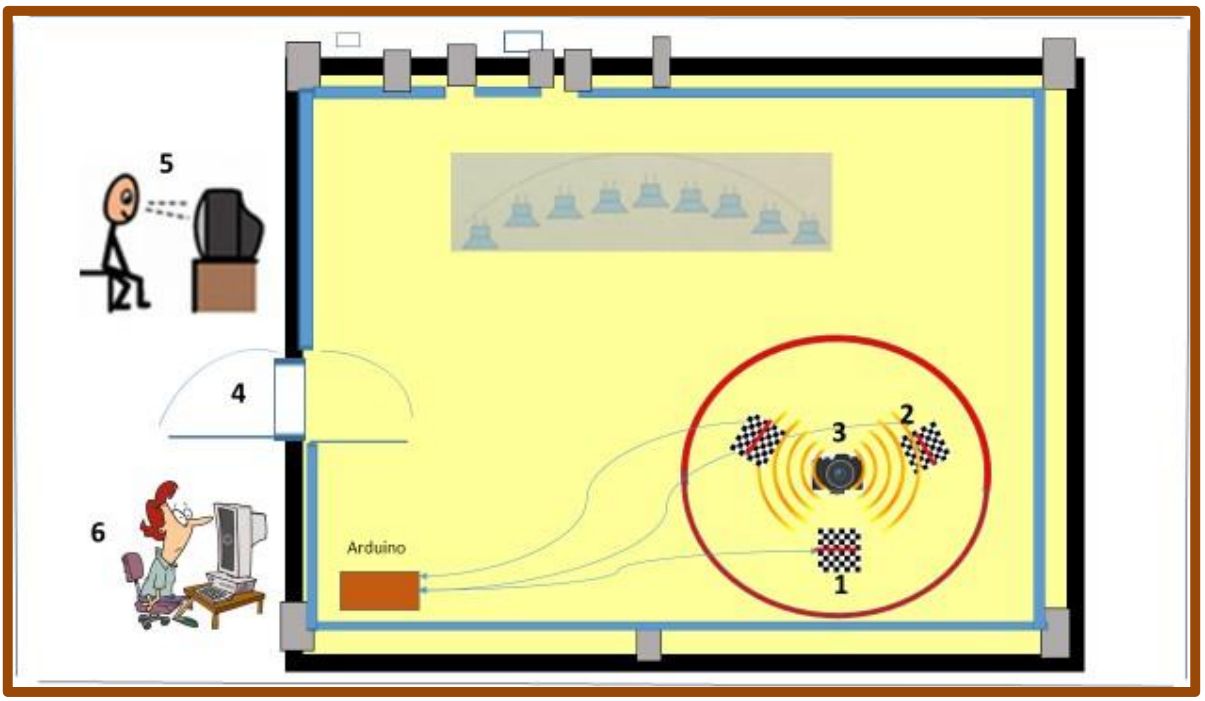

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Fig. 1 Top view of the participant test apparatus; No 1 - three locations were marked with black and white chequered tiles, No 2 - infrared beam, No 3 - loudspeaker, No 4 - entrance, No 5 - monitoring system, No 6. Computer controlling the experiment

2.4. Stimuli

In this experiment, participants were presented with four types of stimuli.

Figure 2 shows a scheme of stimuli (as an example). All stimuli were made from five instruments: shaker, clave, cowbell, djembe, and kick to create the stimuli, these instruments are shown as colored dots in the scheme.

The stimuli were categorized as follows:

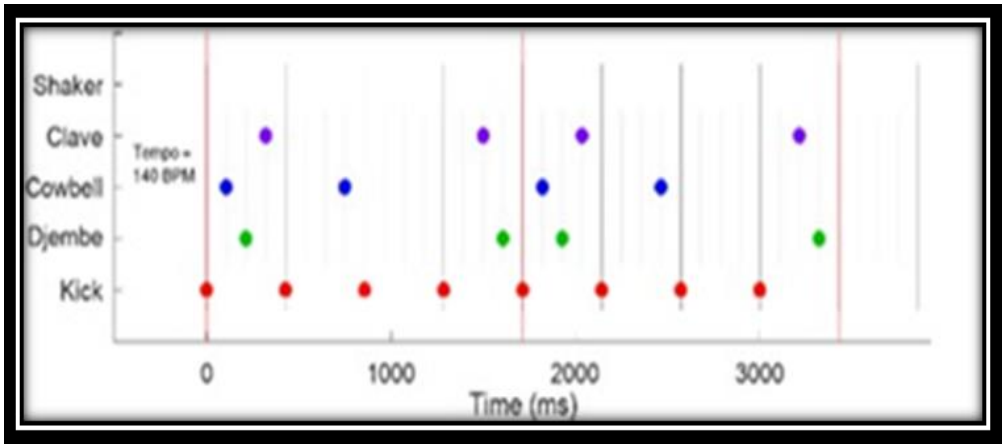
A. Rhythmic stimuli (both repetition and regularity): a beat is present and each section has the same structure**.**

B. Regularity stimuli: a beat is present, and where the structural arrangement varies from section to section.

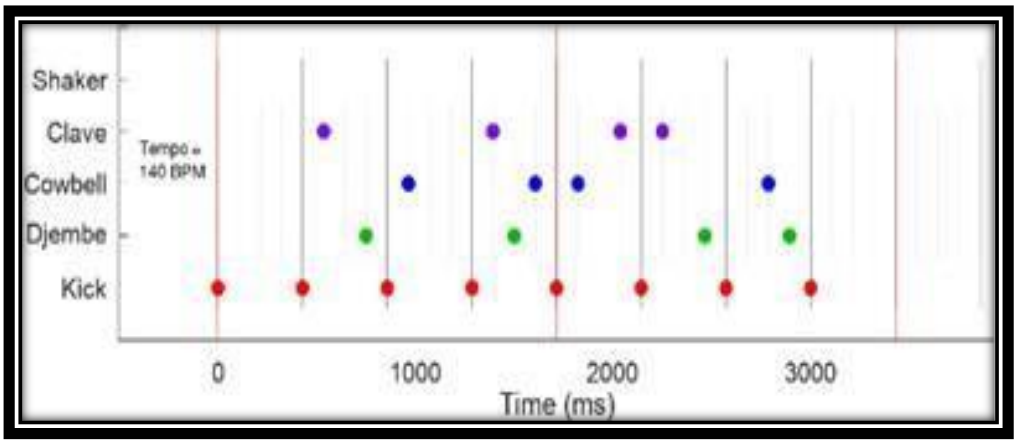
C. Repetition stimuli: absence of a recognizable beat, where each section has the same structure.

D. Arrhythmic stimuli (neither repetition nor regularity): absence of a recognizable beat, where the structural arrangement varies from section to section.

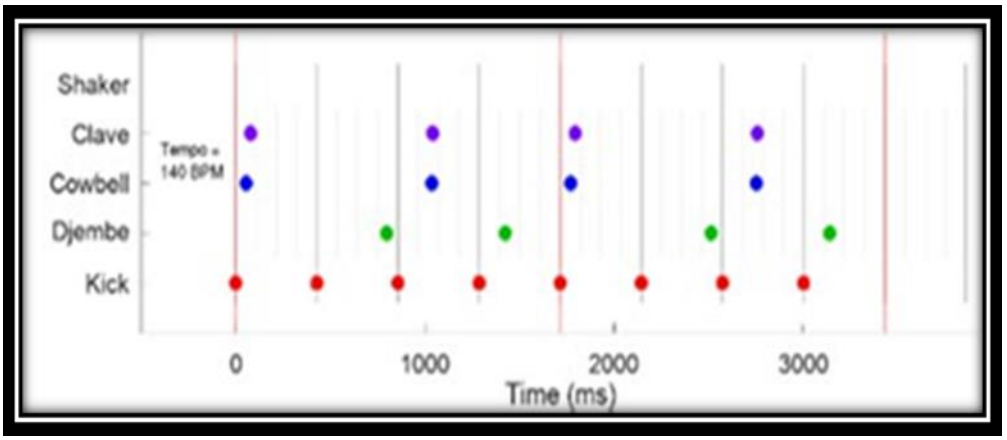
A



B



C



D

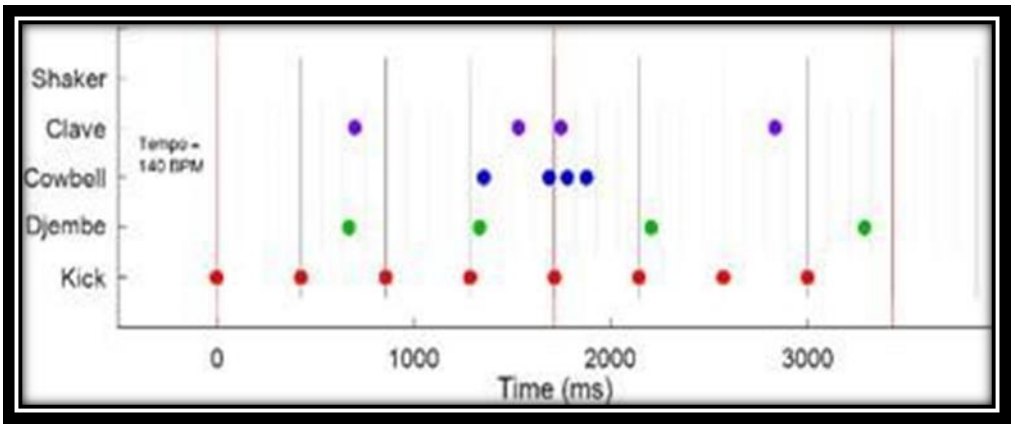


Figure 2. In two sections, the five utilized instruments: shaker, clave, cowbell, djembe, and kick (their timing presented by the placement of different colored dots). (A) rhythmic stimuli (B) regularity stimuli (C) repetition stimuli (D) arrhythmic stimuli.

2.4.1 Table 1. Relevant musical terms (Hoeschele et al., 2015)

beat	the underlying pulse, or unit of time, in music/ The beat, is the underlying pulse of music
entrainment	the ability to perceive a beat in music and align bodily movement with it
musicality	the capacity that underlies the human ability to perceive, appreciate, and produce music
rhythm	a non-random repetitive temporal auditory pattern
vocal learning	long-term modification of vocal production by imitation
regularity perception	detecting a regular beat or rhythmic "tactus" from a series of events characterizes pulse perception (Fitch, 2013).
meter perception	understanding meter perception entails organizing events into hierarchical trees with varying levels of "strength" or perceptual prominence (Fitch, 2013).

2.5. Study procedure

After completing the consent form, participants were given a verbal explanation of the experimental procedure. They were informed that the experiment would consist of six sessions, each lasting 5 minutes. Clear instructions were given and participants were instructed to enter the anechoic chamber through the designated entrance door. This briefing aimed to ensure a full understanding of the structure of the study and the role of the participants when entering the experimental room. They were told that the experiment start when they were entering a test room where sounds were played at a comfortable level set at 70 dB, precisely in front of the loudspeaker. Participants were explicitly informed that they were free to explore the space inside the circular area marked with red tape and freely navigate and engage with the environment, with the added guidance that they could step on the three distinctly marked spots, each featuring footprints on the tiles, at their discretion. The computer recorded the amount of time participants spent with each type of stimulus in each session in order to calculate the relative time spent at each location **(**the experimental functionality was programmed in Python and used an Arduino**).** Arduino and Python were used together to create a system that plays sound through a playback device. A Python program was written to control the logic and flow of the application. The Python script acts as the digital foundation and user guide for assigning different stimuli to different locations, as well as logging and storing the collected data on the computer.

The Arduino acts as a hardware interface, handling communication between the Python program and the physical world. The Arduino can read sensors, buttons or other input devices and send signals to the Python program based on the input. The communication between Python and Arduino is done through a serial connection where the Arduino sends data to the Python program. Based on the input received from the Arduino, the Python program can send commands back to the Arduino. For example, in my experiment I wanted to trigger a sound,

the Python program can send a signal to the Arduino, which interprets it and activates a connected sound playback device. The actual sound playback was usually done by an external sound playback device connected to the Arduino. This is a speaker capable of playing sound. The Arduino code interprets signals from Python and controls the playback device accordingly.

Participants were informed that after the first 5 minutes I would enter the room to stop the session. To accommodate their comfort and pace, they were explicitly told that they had the option to take a break after each session or to continue seamlessly into the next session. This flexibility was emphasized to ensure that participants felt comfortable and in control of their engagement with the study, allowing them to manage the experimental sessions according to their preferences and comfort levels. At the end of all six sessions in the anechoic chamber, participants were directed to the main laboratory area outside the anechoic chamber. Here they were asked to listen to each stimulus again via a computer. This phase was designed to elicit valuable feedback and insights from the participants and to allow them to articulate their perceptions and preferences regarding the auditory stimuli they had encountered during the experimental sessions in the anechoic chamber.

The survey encompassed three questions pertaining to each of the four stimuli: rhythm, repetition, regularity, and arrhythmic. Participants were prompted to provide a rating between 1 and 7 points for each stimulus in response to each question. This survey design aimed to capture nuanced feedback, allowing participants to express their subjective assessments of the auditory stimuli across different dimensions. By assigning points to each stimulus based on their preferences or perceptions, participants contributed valuable data for a comprehensive analysis, enhancing the study's capacity to interpret their preferences and responses to distinct auditory features. The questions consisted " How beautiful did you find the audio file? How interesting did you find the audio file? How meaningful did you find the audio file?" (Appendix C). In the concluding phase of the study, participants were requested to fill out a comprehensive questionnaire delving into their musical history. This survey covered various

aspects, including their familiarity with music, linguistic background, gender, age, and nationality. The purpose of this questionnaire was to gather detailed information about the participants' musical experiences, linguistic influences, demographic characteristics, and cultural backgrounds. By exploring these factors, the study aimed to contextualize individual responses to the auditory stimuli, allowing for a more nuanced interpretation of the influence of participants' musical backgrounds and demographic attributes on their preferences and interactions with the experimental stimuli (Appendix B).

2.6. Data analysis

The statistical analysis of the collected data was conducted utilizing SPSS Statistics (licence: IBM SPSS Statistics Subscription) version 29.0.1.0. A crucial preliminary assessment revealed that the data exhibited a normal distribution, as confirmed by the Kolmogorov-Smirnov test with a significance level (p) exceeding 0.05. This indicated that the assumptions for normality were met. To assess potential variations in the time spent with the four types of stimuli within the place preference apparatus, an analysis of variance (ANOVA) was employed.

Turning to the analysis of the questionnaire results, a Friedman's test was conducted on the ratings provided in the post-test survey. This statistical test, tailored for ordinal data, enabled a comprehensive evaluation of participants' subjective assessments across the various stimuli categories. By applying Friedman's test, I aimed to discern any significant differences in participant ratings, offering a more in-depth understanding of their preferences and responses to rhythm, repetition, regularity, and arrhythmic stimuli.

3. Results

3.1. Time spent with the four stimulus types in the place preference paradigm

3.1.1Repeated measures ANOVA:

In order to rigorously assess whether the average time spent with distinct types of stimuli in the apparatus significantly deviated from chance levels (set at 0.05), I conducted a repeated measures ANOVA encompassing data from all 38 subjects. The outcome of this statistical analysis revealed a significant difference in the duration of interaction across various stimuli types. The Wilks' Lambda statistic, with a value of 0.59, indicated a substantial effect, and the overall F-statistic ($F(3, 35) = 7.82$) demonstrated statistical significance at a level of $p < 0.001$.

This outcome underscores a meaningful difference in the time allocated to different stimuli categories within the experimental framework, emphasizing the salience of participants' preferences and interactions with rhythm, repetition, regularity, and arrhythmic stimuli.

Paired samples t-test:

In order to assess potential differences in the relative time spent with each stimulus across all sessions, I conducted a paired samples t-test for six paired stimuli. Since the overall ANOVA was significant, it is reasonable to conduct this analysis. Recognizing the need to control for the increased probability of Type I errors due to multiple comparisons, I applied a Bonferroni correction to adjust significance levels. The Bonferroni adjustment involved dividing the conventional alpha level (0.05) by the number of pairwise comparisons, resulting in a corrected significance threshold of 0.008 (0.05/6). This adjustment was implemented to mitigate the risk of erroneously identifying significant differences and uphold the integrity of the statistical analysis. By employing this stringent criterion, the study aimed to ensure a more conservative approach to hypothesis testing, minimizing the likelihood of false positive results in the interpretation of paired stimuli comparisons across subjects and sessions. The statistical analysis revealed compelling findings regarding participants' relative time allocation to different stimuli pairs across all sessions. Specifically, participants demonstrated a significant preference for spending more time with rhythmic stimuli compared to arrhythmic stimuli [t (-

4.24), p < .001], as well as a significant preference to spend more time with stimuli-characterized by regularity in contrast to arrhythmic stimuli [t (-3.76), p < .001]. However, no significant differences were observed in the time spent on the arrhythmic stimuli compared to repetition stimuli [t (-1.36), p = 0.180], time spent on the regularity stimuli compared to repetition [t (1.08), p = 0.28], time spent on the rhythmic stimuli compared to repetition [t (-1.45), p = 0.16], and time spent on the regularity stimuli compared to rhythmic [t (-1.78), p = 0.08]. Figure 3 shows the mean and standard error for the time spent with the different stimulus types.

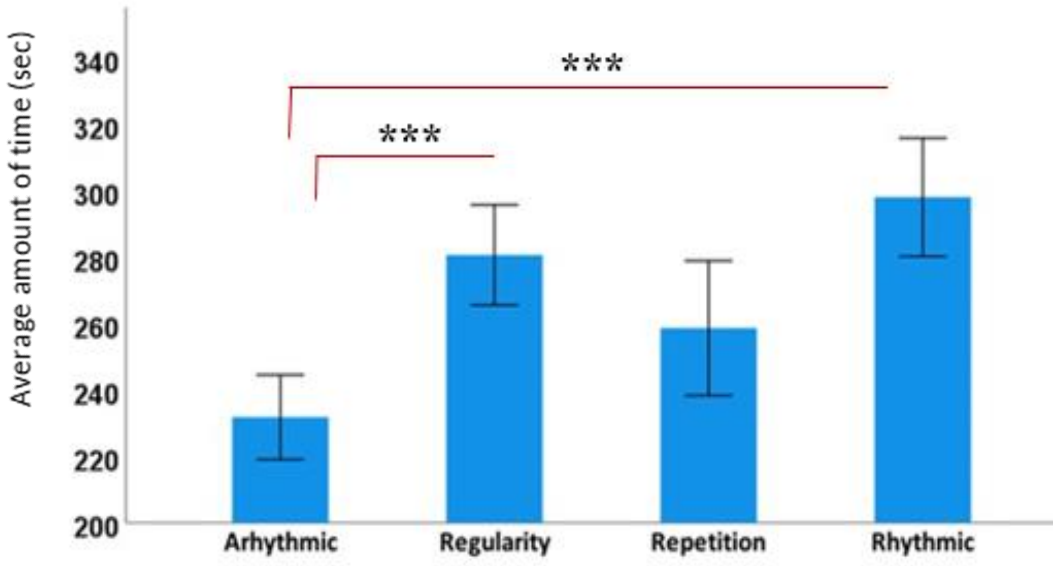


Figure.3. The average amount of time spent on the different types of stimuli within the apparatus, with error bars indicating the range of variation indicated by ± 1 standard error of the mean. The stars indicate that there are significant differences in the average amount of time spent on rhythmic versus arrhythmic stimuli, and significant differences in the average amount of time spent on regular versus arrhythmic stimuli.

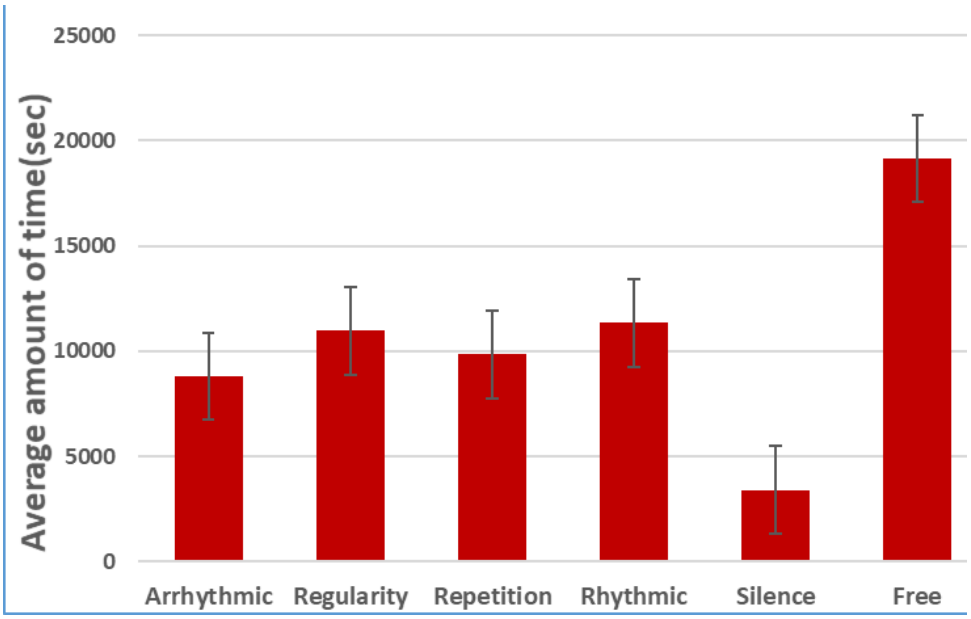


Figure.4. The average amount of time spent with different types of stimuli, silence and free state* within the apparatus, with error bars indicating the range of variation indicated by ± 1 standard error of the mean.*Free state, defined as the situation where participants were engaged not in any of the three locations in the place preference apparatus.

3.2. Interest ratings for each of the four stimuli in survey responses

I conducted a Friedman's test on the ratings provided by participants in the survey. The results for the first question (How beautiful did you find the audio file?), chi-squared (df= 3, N=38) =56.622), p< .001 show significant differences between four stimuli therefore I conducted paired samples t-test. The results of paired samples t-test for the first question showed " a significant preference for the rhythmic stimuli compared to the arrhythmic stimuli (t=-8.130, p<.001), regularity stimuli (t=-5.034, p<.001), repetition stimuli (t=-7.440, p<.001), and a significant preference for the regularity stimuli compared to the arrhythmic stimuli (t=4.444, p<.001)". The results for the second question (How interesting did you find the audio file?), chi-square (df= 3, N= 38) =25.293, p<.001 show significant differences between four stimuli. The results of paired samples t-test showed a significant preference for the rhythmic

stimuli compared to both the arrhythmic stimuli (t=3.872, p<.001) and repetition stimuli (t=-5.129, p<.001), and regularity stimuli compared to the arrhythmic stimuli (t=-5.279, p<.001)". The results for the third question (How meaningful did you find the audio file?), chi-square (df= 3, N= 38) =34.986), p<.001 show significant differences between four stimuli. The results of paired samples t-test showed a significant overall preference for the rhythmic stimuli compared to the repetition stimuli (t=-5.376, p<.001).

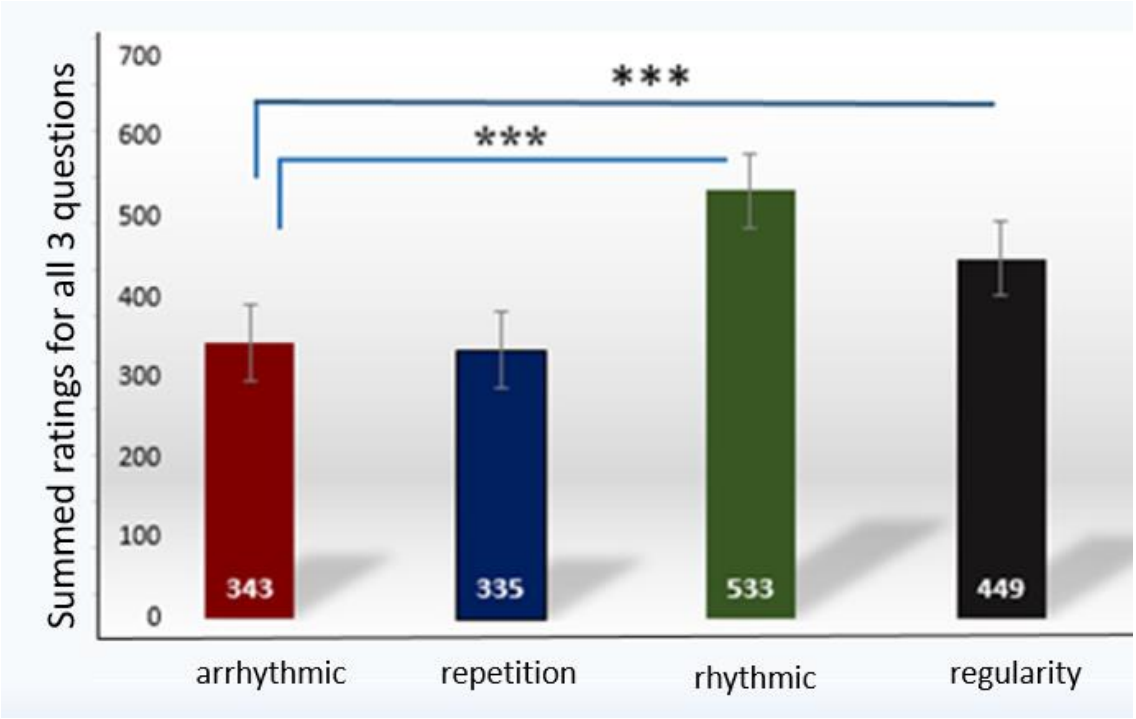


Figure. 5. The preference ratings given by the participants in the post-test survey for the ratings of the four stimuli. The stars indicate that there are significant differences in the participants' ratings of rhythmic versus arrhythmic stimuli, and significant differences in the participants' ratings of regular versus arrhythmic stimuli.

4. Discussion

The present thesis addressed the question of whether humans prefer repetition or regularity in rhythmic patterns. The results from both the place preference paradigm and the survey, show a significant preference among participants towards regularity compared to arrhythmic stimuli. Although the results did not explicitly indicate a preference for regularity over repetition, the fact that only regularity was preferred to arrhythmic stimuli implies that regularity holds greater significance for participants. Additionally, the survey results further reinforce the observed preference, demonstrating a significant overall preference for regularity over arrhythmic stimuli. The survey, being a broader measure, captures a larger perspective on participants' preferences, strengthening the argument that regularity holds a distinct and meaningful appeal in the context of rhythmic patterns. While the results of my study did not explicitly show a preference for regularity over repetition, the fact that only regularity and not repetition was preferred over arrhythmic patterns implies that, in the absence of regularity, participants did not show a strong preference for mere repetition. This suggests that, in the hierarchy of preferences, regularity may indeed be more influential or fundamental than repetition in the perception of rhythmic patterns by humans.

The observed preference for regularity in my study indirectly supports the notion that beat perception and synchronization are connected to two main factors including regularity and the auditory system (Patel et al., 2005). It is worth looking at how this support might be explained: Regularity stimuli often lead to predictability, which may indicate that the brain finds it easier to synchronize with and perceive beats that follow predictable patterns (Savage et al. 2015). Regular patterns may be processed more efficiently by the auditory system, making it easier for people to synchronize their movements or perceive the underlying beat. This connection forms a crucial aspect of human musical behavior, encompassing activities such as dance (Patel et al., 2010).

An alternative explanation for participants' preference for regularity in my study may be related to the idea that musical rhythm involves not only the extraction of beats, but also the hierarchical grouping of sound events into distinct metrical patterns (Longuet-Higgins, 1979; Temperley, 2001; Honing, 2012). These findings suggest that participants are naturally drawn to music with clear hierarchical structures, which aids in the perception of metrical patterns. Based on these findings, Patel (2005) introduces another dimension by suggesting that music contains layered rhythms that form metrical structures, contributing to beat perception and synchronization. The observed preference for regularity in my study supports Patel's suggestion, indicating that participants are more likely to engage with music that has structured and layered rhythmic elements. This is consistent with the idea that such structures enhance beat perception and support synchronization.

Additionally, Fitch's (2013) study highlights the importance of structured regularity in rhythms for the accurate execution of performance and movement in response to music and dance. The preference for regularity found in my study is aligned with Fitch's concept, suggesting that individuals may prefer music with clear and structured rhythmic regularity because it facilitates more precise and coordinated responses in terms of movement and performance. Similarly, Savage et al. (2015) explored the significance of regular structure in providing predictability in performance and facilitating the planning of group dance experiences, which are integral elements in the human musical system. The findings of my study, revealing a preference for regularity among participants, resonate with the insights of Savage et al. (2015) regarding the role of predictability in music. The inclination toward structured rhythmic patterns suggest a natural desire for easily anticipated and synchronized musical experiences. In activities like group dance, these rhythms establish a foundation for synchronized movements, and participants with a preference for regularity likely acknowledge the role of rhythmic predictability in enhancing collective engagement and coordination. This

inherent inclination toward predictability contributes to both individual enjoyment and seamless coordination in social settings.

The preference for regularity over repetition observed in the present study is consistent with studies in the field of dance by Fitch (2015) and Wilkins & Clayton (2016), which emphasize the role of rhythm as a central aspect of human musicality in uniting individuals in groups, thereby facilitating synchronisation. This synchronisation is important for human society and social bonding (McNeill, 1995).

For example, music may function as a signaling system for mate choice, which means that the evolution of musical skills may be rooted in communication related to mate choice (Miller, 2000). This concept suggests that musical expression may have played a role in providing information about an individual's fitness and desirability as a potential mate. Scholars such as Hagen & Bryant (2003) suggest that the development of musicality may have served as a mechanism to promote pair bonding. In this view, music serves as a tool for individuals to communicate their commitment to group dynamics, thereby promoting social bonding and cooperation within communities. In addition, infants as young as 3-4 months of age show vocal changes and synchronized limb movements to rhythmic dance music (Fujii et al., 2014). Thus, rhythmic sounds and movements are fundamental to communication and interaction with others at all stages of development and are critical for communication and social interaction (McGurk and MacDonald, 1976). Therefore, these findings suggest that the idea that musicality is not a single trait with a fixed purpose, but a combination of skills that serve different functions (Fitch, 2015), mainly related to social connection, highlighting that the role of music is to strengthen social bonds and personal connections (Savage et al., 2021).

Another study suggests that although repetition contributes to memorization (Merriam, 1964), it also has the potential to induce boredom (Miller et al., 1994) and a lack of distinctive features, hindering music's role as a cue for social identity (Savage et al., 2021). Which may

provide an explanation for the observed preference for regularity compared to repetition in my experiment. These finding suggest that the preference for regularity over repetition in musical patterns arises from the human brain's tendency to balance predictability and novelty, with regularity providing a structured foundation that allows for subtle variation (Savage et al., 2015; Laland, Wilkins, & Clayton, 2016).

In case of non-human animals, the existing knowledge indicates that, including some birds and mammals, do exhibit beat perception and synchronization capabilities. For instance, animals like the sulfur-crested cockatoo (*Cacatua galerita*), California sea lions and rats (Patel et al., 2009; Cook et al., 2013; Ito et al., 2022) have demonstrated this ability to synchronize movements accordingly. However, determining whether animals perceive and construct hierarchical metrical structures from periodic events based on behavioral data alone is challenging (Fitch, 2013). Previous work (Hoeschele et al., 2016) has shown that female budgerigars prefer rhythmic stimuli. This work shows that female and male budgerigars have different patterns of listening to these stimuli. This work supports the idea that budgerigars may share with humans the enjoyment of the rhythmic aspect of musicality. Previous work by Afroozeh et al. (in prep) and Kopaç et al. (in prep) on female budgerigars suggests that both aspects of rhythm (repetition and regularity) are important to them. While the results of the present study on humans showed a preference for regularity over repetition. For humans, unlike budgerigars, regularity is important for synchronization, and synchronized movement allows individuals to engage with rhythm, and dance together in social bonding (Savage et al., 2015). In contrast, male budgerigars perform solo displays of head bobbing behavior to which females attend. To the best of our understanding, budgies do not appear to do need to synchronize together when engaging in displays with one another.

Fitch (2013) has mentioned it is not yet known how animals understand rhythmic patterns, although we do know that they can extract a beat. They may not be able to perceive the fine

details of meter patterns (hierarchical organization of temporal events based on stress and other spectral properties, such as loudness alternation, and pitch variation) in the same way that human beings can. There is still a lot to learn about how they perceive different rhythms.

Overall, more research is needed to understand how animals really perceive and interact with rhythmic patterns, shedding light on the various ways animals experience music. For instance, Fitch (2013) suggested parrots are considered one of the species that offer significant potential for studying metrical structure through the non-invasive measurement of event-related potentials. This would give us a glimpse into other species and how they differ from, or share the characteristics of, human musicality.

My results also show a significant preference for rhythmic over arrhythmic stimuli, consistent with the previous study by Hoeschele et al. (2016). However, they did not discriminate some of the stimuli. One possible explanation is that participants perceived these stimuli as too similar to discriminate.

4.1. Social and cultural aspects of rhythm perception:

Honing et al.'s (2017) suggest that there are cultural differences in musical habits that appear to influence perceptions of meter in music. There was a preference for regularity over repetition in my results however, culture may have played a role in this result. Further research will be needed to reveal effect of cultural differences in musical habits and perceptions of meter in music. Recent studies have proposed the perspective of predictive coding (Rao and Ballard, 1999; Friston, 2005; Clark et al., 2013).

To understand the perception of meter, it is important to explore how the environment interacts with this process. Predictive coding is based on the notion of using past experience and posits that the brain's fundamental function is to interpret sensory input using hierarchical generative patterns acquired from previous encounters (Clark et al., 2013). This theoretical framework highlights the

idea that the brain actively seeks to anticipate and explain incoming sensory information based on learned patterns, providing valuable insight into how environmental factors can shape the perception of regularity. Honing et al. (2017) have provided a predictive model of regularity perception, which is based on a predictive coding perspective of perception. They suggest that this computational model of regularity perception could be used in further cross-cultural research to determine whether the preference for meter is due to a perception of meter formed by previous exposure.

4.2. Language and rhythm perception:

Given that the participants came from fifteen countries with different languages, the majority of them shared similar conditions in terms of two key factors: proficiency in both German and English and at least five years of music education. Some scholars suggest that language is an evolutionary adaptation that has led to the development of musicality as a by-product (Pinker, 1997). This may therefore be related to the preference for regularity over repetition in my results. Many researchers point out that although music and language have fundamental differences, they have much in common in the way they are structured. Even though the two systems are different, they also have a lot of overlap in their basic structural meaning (e.g., similar neural substrates for processing pitch, rhythm, and syntax; Brown, 2017; Fitch, 2006; Patel, 2008; Peretz & Coltheart, 2003).

Recent studies have suggested that the ability to understand and create music may have had a significant influence on how languages evolved over time (Brown, 2017; Darwin, 1871; Fitch, 2010; Shilton, Breski, Dor, & Jablonka, 2020). However, determining the influence of language on the interpretation of regularity or repetition in my study is currently challenging and requires further investigation before definitive conclusions can be drawn. What seems clear, however, is that more research is needed to understand how regularity is perceived by people across cultures.

4.3.Future research direction:

Future research into musicality could look at other groups of birds, both vocal non-learners and some vocal learners, which are considered to be more advanced in their cognitive abilities to see whether these animals have more developed rhythm perception.

This investigation would not only enhance our knowledge of the biology and evolution of music but also shed light on the potential connections between rhythmic abilities and language in the animal kingdom. Understanding how animal's process metrical information could provide new perspectives on the evolutionary links between music and language, ultimately contributing to our understanding of linguistic and communicative skills in both humans and animals. In essence, addressing this question would deepen our understanding of musical cognition and its potential connections to the broader cognitive landscape in the animal kingdom.

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7. Apendix

Appendix A. Abstract German

Musik ist ein grundlegender Bestandteil der menschlichen Existenz und spiegelt unsere kognitiven Fähigkeiten wider. Es ist üblich, dass Menschen ihre Körperbewegungen mit dem Rhythmus synchronisieren. Bei einer Reihe von Papageien wurde festgestellt, dass sie ihre Bewegungen mit einem rhythmischen Pulsschlag synchronisieren. Eine kürzlich durchgeführte Studie hat gezeigt, dass weibliche Wellensittiche an beiden Elementen rhythmischer Reize interessiert sind, die aus Wiederholung und Regelmäßigkeit bestehen. Da wir nicht wissen, welches rhythmische Element für den Menschen von Bedeutung ist, ist ein Vergleich mit Wellensittichen schwer möglich.

Deshalb möchte ich in der vorliegenden Studie diese Frage beantworten: Bevorzugen Menschen Wiederholungen oder Regelmäßigkeit in rhythmischen Mustern? Ich präsentierte den Teilnehmern vier Arten von Reizen: Wiederholung, Regelmäßigkeit, beides oder keines von beidem in einem akustischen Platzpräferenzparadigma mit drei Bedingungen (die Teilnehmer durften eine Umgebung erkunden und wählen, ob sie Geräusche oder Stille hören wollten). Ich habe gemessen, wie viel Zeit die Teilnehmer mit den vier Arten von Reizen im Verhältnis zueinander verbrachten, um die relative Attraktivität zu messen. Die Ergebnisse zeigten eine signifikante Präferenz für regelmäßige gegenüber unrhythmischen Reizen und eine signifikante Präferenz für rhythmische gegenüber unrhythmischen Reizen. Die Umfrageergebnisse zeigten auch eine Präferenz für rhythmische gegenüber anderen Reizen und eine Präferenz für Regelmäßigkeit gegenüber arrhythmischen, aber nicht repetitiven Reizen. Zusammenfassend lässt sich sagen, dass die Ergebnisse von Wellensittichen und Menschen darauf hindeuten, dass die Wertschätzung von Rhythmus nicht nur beim Menschen vorhanden ist. Diese Ergebnisse unterstützen, dass Regelmäßigkeit für Synchronisation, soziale Bindung und Tanz beim Menschen wichtig ist.

Während weibliche Wellensittiche Regelmäßigkeit und Synchronisation in der Gruppe nicht nutzen.

Appendix B. Demographic questionnaire

DEMOGRAPHIC QUESTIONNAIRE Participant # _____

1. Age: _____ Sex (Circle one): Male Female

2. Have you ever had any musical training? (Circle one) Yes No
→ If No, please skip to question 7.

3. What was the first instrument (including voice) that you were trained with? _____

4. Please list how many years of private lessons, group lessons, and self taught training you have had and with what instruments (please list an instrument twice if you have had more than one type of training with that instrument).

Instrument	Type of Training (Circle one)	# of years
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____
_____	Private Lessons/Group Lessons/Self-Taught	_____

5. Which of the following best describes you as a musician? (Circle one)

Professional (musical performance, composition, or teaching as a reliable source of income)	Semi-Professional (musical performance, composition, or teaching as an occasional source of income)	Amateur (musical performance, composition, or teaching as a sideline or just for fun)

6. Can you read music? (Circle one) Yes No

7. What is your first language? _____Would you say you learned a specific dialect of that language? If so, which one? _____

8. What other languages do you speak **fluently** and how long have you spoken them?

Language	# years
_____	_____
_____	_____
_____	_____

9. What countries have you lived in and how long have you lived there (including your country of birth and country of current residence)?

Country	# years
_____	_____
_____	_____

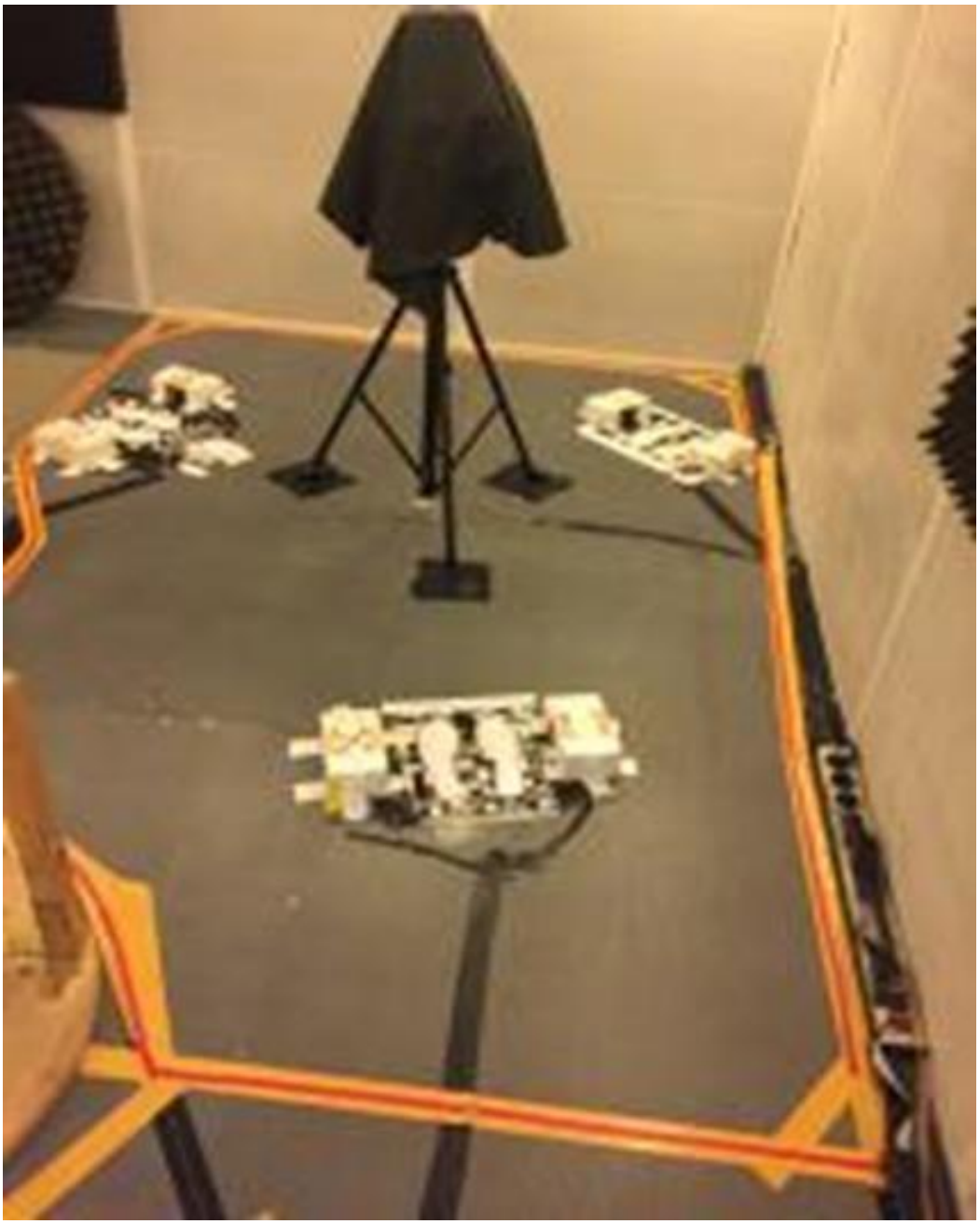
10. What do you think the experiment you just did was about?

Appendix C. survey test

Participant No:

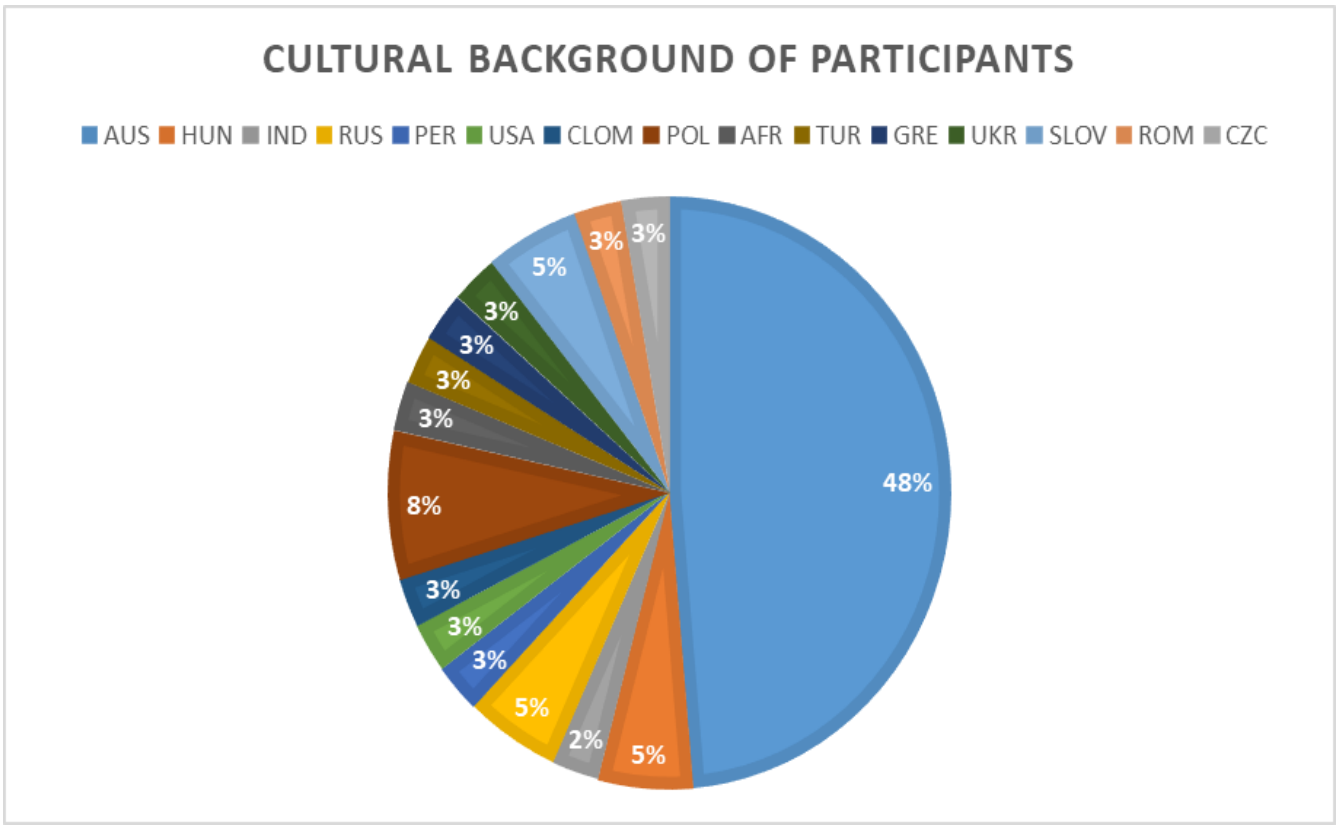
(A) → How beautiful did you find the audio file? not at all very 1 2 3 4 5 6 7 → How interesting did you find this audio file? not at all very 1 2 3 4 5 6 7 →How meaningful did you find the audio file? not at all very 1 2 3 4 5 6 7	**(P)** → How beautiful did you find the audio file? not at all very 1 2 3 4 5 6 7 → How interesting did you find this audio file? not at all very 1 2 3 4 5 6 7 →How meaningful did you find the audio file? not at all very R_1 2 3 4 5 6 7
(R) → How beautiful did you find the audio file? not at all very 1 2 3 4 5 6 7 → How interesting did you find this audio file? not at all very 1 2 3 4 5 6 7 →How meaningful did you find the audio file?? not at all very 1 2 3 4 5 6 7	**(M)** → How beautiful did you find the audio file? not at all very 1 2 3 4 5 6 7 → How interesting did you find this audio file? not at all very 1 2 3 4 5 6 7 →How meaningful did you find the audio file? not at all very 1 2 3 4 5 6 7

Appendix D. Photo of apparatus

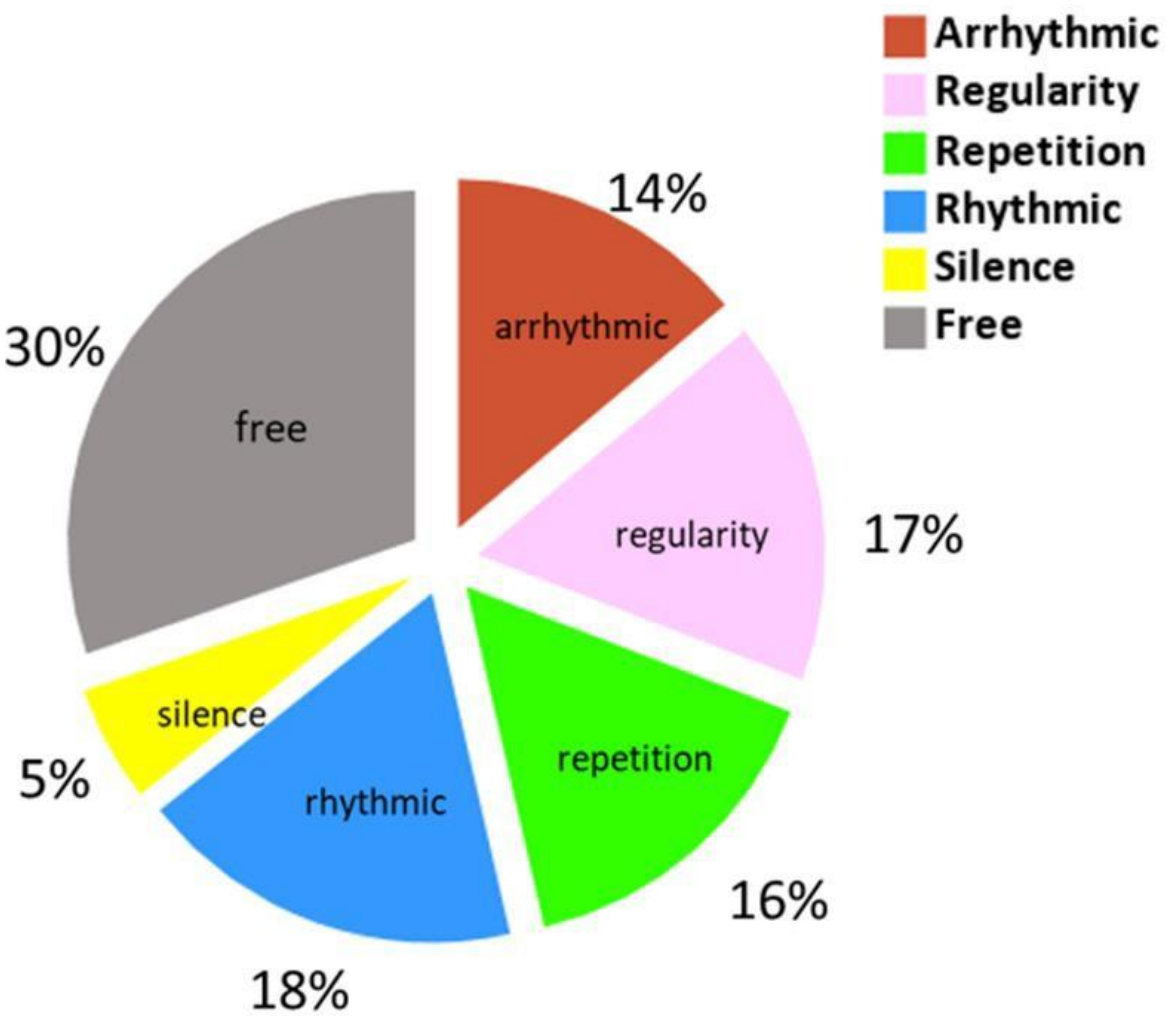


Appendix E. Additional Figures of the results

Cultural background of participants



Time spent on all states for participants



Appendix F. Volunteer Information Sheet

Volunteer Information Sheet
Title of Study: Rhythm pattern preference

Dear volunteer,

thank you for taking part in this study which is part of a master thesis of MEi:CogSci.

Your task will be to explore the sound room.

The data collected will be stored anonymously. Conclusions who you are will thus not be possible.

You can stop the experiment at any time without giving any reason. In this case you will be paid for the time you participated up to then.

The duration of the study is approximately 45-60 minutes.

You will receive a full debriefing after you completed the study. You can still withdraw after the debriefing. In that case, all your data will be deleted.

Do you have any questions?